GBP

Grassland Bypass Project

Annual Report 2001–2002

Drainage Control Activities
Flow and Salinity Monitoring
Water Quality Monitoring
Flow, Salt and Selenium Mass Balances
Project Impacts on the San Joaquin
Biological Effects
Toxicity Testing
Sediment Monitoring
Sediment Quantity
Quality Control

GBP

Grassland Bypass Project

Prepared by SFEI for the Grassland Bypass Project Oversight Committee

U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey
Central Valley Regional Water Quality Control Board
California Department of Fish and Game
San Luis & Delta-Mendota Water Authority

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October 1, 2001 – December 31, 2002

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Grassland Bypass Project

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Introduction

The Grassland Bypass Project (GBP) completed the first year of Phase II on December 31, 2002. This report documents results from the monitoring efforts from October 1, 2001 through December 31, 2002. One feature of the Phase II program was to adopt a calendar year reporting and compliance schedule. This report not only has the full calendar year of 2002 but also the three preceding months of October, November, and December 2001. Both Water Year (WY) 2002 and calendar year 2002 results will be discussed. Information from the initial five-year program are included where appropriate. One function of this report is to document results from the multi-agency data collection effort. The report builds upon previous information allowing for the discernment of changes in environmental conditions over time.

During the year, the Data Collection and Reporting Team (DCRT) continued to meet and review project data and associated reports. The following reports were reviewed and published during the year: monthly reports (15), quarterly data reports (5), and the WY 2001 annual report.

This annual report consists of technical chapters prepared by the agency staff responsible for their data collection effort within the GBP monitoring program and compiled by the San Francisco Estuary Institute (SFEI).

Project Authorization

The U.S. Bureau of Reclamation (Reclamation) signed a Finding of No Significant Impact (FONSI) on November 3, 1995 for the execution of an agreement with the San Luis and Delta-Mendota Water Authority (Authority) to use a 28-mile segment of the San Luis Drain. This segment conveys agricultural drainage waters from the Grassland Drainage Area (GDA) to the San Joaquin River via a 6-mile segment of Mud Slough (North). A map of the GBP area and a schematic diagram are presented in Figures 1 and 2. Analysis from an environmental assessment dated April 1991, and supplemented in November 1995, resulted in the FONSI. A Use Agreement (UA) was also signed on November 3, 1995 between USBR and the Authority. The UA provided the terms and conditions for the use of the San Luis Drain until September 30, 2001.

A second phase of the project was authorized during an extensive review period covering most of 2000 and 2001. Documents for the continuation of the Grassland Bypass Project are listed in the Reference section of this chapter. All of the documents are available upon request.

The project continues the commitments made by participating agencies to address environmental benefits and risks. These commitments include the following:

- To ensure that progress continues toward long term resolution of agricultural subsurface drainage management activities,
- To ensure that there are no significant adverse effects to fish and wildlife, other environmental resources, and public health, and
- To ensure that the above listed commitments are implemented and addressed as part of the project.

Documented benefits include the following:

- Agricultural subsurface drainage water has been removed from the Grassland Water District (GWD) wetland supply channels allowing refuge managers to receive and apply all of their fresh water allocations according to optimum habitat management schedules.

- Removal of agricultural subsurface drainage water from the GWD wetland supply channels has reduced the selenium exposures to fish, wildlife, and humans in the wetland channels and Salt Slough.

- Combining agricultural subsurface drainage flows within a single concrete-lined structure allows for effective concentrated monitoring leading to detailed evaluation and effective understanding of drainage flows and associated selenium loads.

- The establishment of an accountable drainage entity has provided the framework necessary for responsible watershed management in the Grassland Basin.

Documented risks included the following:

- Combining agricultural drainage flows within the San Luis Drain has resulted in an increase in selenium and other constituents discharged into Mud Slough (North). These constituents are above the levels historically discharged to Mud Slough (North) and could have an adverse environmental effect on six miles of Mud Slough (North).

- Agricultural drainage flows entering wetland channels during floods.

2001-2002 Highlights

During WY 2002 and calendar year 2002, monthly selenium loads discharged from the terminus of the San Luis Drain were all below the load values agreed upon in the Phase II Use Agreement (Figure 3). The total selenium load discharged during the 2002 Water Year was 3,939 pounds, about 73 percent of the load limit specified in the 2001 Waste Discharge Requirement. The total selenium load discharged during the 2002 Calendar Year was 4,176 pounds, or 78 percent of the calendar year load limit. For comparison purposes, monthly selenium discharges are provided for water years 2001, 2000, 1999, 1998 and 1997 are presented in Table 1. The monthly selenium discharges for Calendar Years 1997 – 2002 are listed in Table 2. The monthly selenium discharge values specified in the new Use Agreement and Waste Discharge Requirement are listed in Tables 3 and 4. The Salinity Load Values and Goals specified in the new Use Agreement are listed in Tables 5a and 5b.

The US Geological Survey installed a new station in the San Joaquin River at Fremont Ford in November 2001. The new station, Site G, measures the flow, salinity, and temperature of water from the Grassland wetlands and other farmlands outside the Grassland Drainage Area. This site was required in the new Waste Discharge Requirement for Phase II of the Project.

The Grassland Area Farmers continued to collect water quality samples from the San Joaquin River at Hills Ferry to compliment quarterly biological monitoring there. The Regional

Water Quality Control Board stopped collecting weekly grab samples at this site in September 1999 due to uncertainty about the source of water.

The revised Monitoring Plan for Phase II of the Project was completed June 2002. The revised Quality Assurance Project Plan was completed in August 2002.

Additional Reports and Studies

Sources of Selenium Studies. Heavy rainfall during the 1997 and 1998 Water Years resulted in selenium load discharges that exceeded the load values specified in the Waste Discharge Requirement and First Use Agreement. On-farm management activities were not able to control excessive rainfall and associated storm runoff within the Grassland Drainage Area. As a consequence, discharges through the San Luis Drain, and in some cases, wetland water supply channels, were above what were planned. The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium. The USGS is preparing a "Transient Three-Dimensional Groundwater Flow Model for the Grasslands and Adjacent Area"; the first draft is due December 2003. The Lawrence Berkeley National Laboratory published a "District Level Water Balance and Selenium Load Model for the Grasslands Area" in December 2003.

Delta-Mendota Canal Water Quality Study. In July 2002, Reclamation began a study of selenium, salinity, and boron in water in the Delta-Mendota Canal and Mendota Pool. These facilities convey source water to the farms and wetlands in the Grasslands Basin. Daily composite samples have been collected from four sites to study the temporal and local changes in water quality due to the operation of the canal, drainage sumps, and tail water inlet structures. Reclamation has published monthly reports and will be preparing criteria for operating the canal and related facilities to improve water quality.

Monitoring Program

The GBP monitoring plan outlines the processes for collecting data to determine if the terms and conditions of the GBP are being met. Flow, water quality, sediment, biota, and chronic toxicity data are collected to assess project impacts (Table 6). The data gathered from this effort allow evaluation of the degree to which the commitments of the Use Agreement and Waste Discharge Requirement are being met.

Water Quality Monitoring in the San Joaquin River at Hills Ferry

As reported in the 2000 – 2001 Annual Report, the Authority has been collecting weekly grab samples from this site since September 2000 to support biological monitoring there and to aid potential future development of revised water quality criteria. The results of water quality analysis at this site for the fifteen month study period are listed in Table 7a; the annual averages since 1997 are listed in Tables 7b and 7c.

Salinity Load Values and Discharge Goals

Appendix E of the Phase II Use Agreement specifies monthly Salinity Load Values (Table 5a) that are intended to guide reductions in salt discharges until such time as the Regional

Board adopts its own numeric limits on salt discharges to achieve compliance with water quality objectives for the San Joaquin River.

To determine if Salt Load Values are being met, the Attributable Discharge of salts will be compared to the Salt Load Value for the time period under consideration. Salt load will be measured at the inlet to the Drain (referred to as "Site A"), except that salt load discharged to the Grassland Water District from the Drainage Area during storm events will be measured at the discharge points into the Grassland Water District, and load to be exempted under Appendices F and G of the Phase II Use Agreement.

If the Attributable Discharge of Salinity exceeds the applicable Salinity Load Value in any given month or year during the term of this Agreement, a Drainage Incentive Fee shall be calculated in accordance with the Performance Incentive System as stated in section IV.B. of this Agreement.

The Salinity Discharge Goals are described in Appendix E of the Phase II Use Agreement and are listed in Table 5b. The Salinity Discharge Goals are lower than the Salinity Load Values because they match percentage reductions in Selenium Load Values and have not been adjusted to reflect the imperfect correlation between discharges of salts and of selenium. The Salinity Discharge Goals are intended to provide a measurement of progress toward reducing salinity discharges commensurate with selenium discharges, but carry no legally enforceable consequences.

Project Organization

The GBP involves the coordination and cooperation of several State and Federal agencies whose authority, interests, or activities directly overlap in one or more aspects of the GBP. These agencies include USBR, USFWS, USGS, USEPA, CVRWQCB, CDFG and the SL&D-MWA. The latter organization includes local drainage and water districts that participate in the drainage activities. The Grassland Area Farmers (GAF) formed a regional drainage entity under the umbrella of the San Luis and Delta-Mendota Water Authority.

Oversight Committee (OC)

The Oversight Committee is comprised of senior level representatives from USBR, USFWS, CDFG, CVRWQCB, and USEPA. The role of the OC is to review process and assure performance of all operations of the GBP as specified in the Phase II Use Agreement, including monitoring data, compliance with selenium load reduction goals, and other relevant information.

The OC meets in a public forum, as needed, to review the status, progress, and monitoring results of the GBP. The OC considers findings and recommendations from the GBP subcommittees. The OC also considers input and recommendations from the San Luis and Delta-Mendota Water Authority and other key stakeholders.

Technical and Policy Review Team (TPRT)

The Grassland Bypass Project Oversight Committee formed the TPRT to serve as staff to the OC. The TPRT consists of a representative from CVRWQCB, CDFG, USBR, USFWS, and USEPA, plus a member from USGS serving as an independent technical advisor. The TPRT is

responsible for obtaining and providing the necessary information, developing alternatives, and formulating recommendations to the OC. This includes producing, or overseeing the production of any analytical and interpretive reports, other than the normal monthly, quarterly, and annual reports, and obtaining appropriate peer or scientific review as necessary. The TPRT is responsible for coordinating, evaluating, and recommending associated research and investigation needs as the GBP proceeds. The TPRT works closely with the DCRT, described below, and, with approval of the OC, may designate and utilize additional subcommittees or task groups as needed to accomplish specific tasks or responsibilities.

Data Collection and Reporting Team (DCRT)

The Data Collection and Reporting Team consists of the agency representatives and contractors responsible for data collection and reporting. The DCRT is responsible for coordinating monitoring activities, identifying and resolving any issues involving data collection and reporting, and making recommendations for revision of data collection and reporting procedures to the TPRT. The DCRT prepared the monitoring plan and the associated Quality Assurance Project Plan (QAPP). The DCRT met five times (quarterly) during the first year of Phase II.

Data Management

Each agency collecting data is responsible for its own internal data quality and data management procedures. These are detailed in the Quality Assurance Project Plan. Each agency submits its data to the San Francisco Estuary Institute for compilation of data and information from all sampling sites in a timely manner.

Reporting

The San Francisco Estuary Institute publishes monthly, quarterly and annual reports. Monthly and quarterly data reports consist of primary data from the 14 key monitoring stations as depicted in Table 6: San Luis Drain (Sites A, B), Mud Slough (Sites C, D, I2, and E), Salt Slough (Site F), wetland channels (Sites J, K, L2, and M2), and the San Joaquin River (Sites G, H, N). The monthly report presents daily and weekly data collected during that particular month, including the calculated selenium load discharged at Site B, the terminus of the San Luis Drain. Quarterly data reports consist of all available data from all stations during a 3-month period. All reports are distributed to the participating parties and are available upon request.

Most of the GBP data reports are available at the Institute's Website:

http://www.sfei.org/grassland/reports/gbppdfs.htm

Annual reports are available upon request from the Bureau of Reclamation, South-Central California Area Office, telephone (559) 487-5133.

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http://www.usbr.gov/mp/mp150/grassland/RelatedDocuments/RODdraftfinal.pdf

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U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. September 28, 2001. Agreement for Use of the San Luis Drain for the Period October 1, 2001 through December 31, 2009. Agreement No. 01-WC-20-2075.
http://www.usbr.gov/mp/mp150/grassland/RelatedDocuments/Agree01-WC-20-2075.pdf

U.S. Bureau of Reclamation, et. al. June 2002. Monitoring Program for the Operation of the Grassland Bypass Project. Prepared by the Grassland Bypass Project Data Collection and Review Team.
http://www.usbr.gov/mp/mp150/grassland/RelatedDocuments/Phase2_monitoring_plan.pdf

U.S. Bureau of Reclamation, et. al. August 22, 2002. Quality Assurance Project Plan for the Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project.

Table 1. Monthly Selenium Discharges from the San Luis Drain (Station B) into Mud Slough Compared to Load Values, Pounds, Water Years 1997 - 2002

Table 1. Monthly Selenium Discharges from the San Luis Drain (Station B) into Mud Slough Compared to Load Values, Pounds, Water Years 1997 - 2002

Water Year	1997		1998		1999		2000		2001		2002		20
	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value
October	348	202	348	248	348	277	348	181	348	146	315	118	308
November	348	252	348	207	348	226	348	193	348	174	315	148	308
December	389	285	389	178	389	239	389	236	389	194	353	170	334
January	533	599	533	335	506	284	479	285	453	255	385	246	359
February	866	878	866	965	823	609	779	541	736	574	619	483	571
March	1066	1,119	1,066	1,600	1,013	799	959	761	906	779	753	586	685
April	799	1,280	799	1,554	759	529	719	549	679	481	577	500	538
May	666	849	666	1,371	633	482	599	427	566	408	488	363	464
June	599	611	599	807	569	524	539	439	509	426	429	397	397
July	599	428	599	615	569	462	539	425	509	416	429	365	397
August	533	348	533	500	506	418	480	324	453	353	387	322	363
September	350	109	350	388	350	275	350	242	350	171	310	241	303
Total Discharge from San Luis Drain		6,960 (1)		8,768 (2)		5,124		4,603		4,377		3,939	
Total Load Limitation	6,660		6,660		6,327		5,994		5,661		5,360		5,027
Discharge as Percent of Total		105%		132%		81%		77%		77%		73%	

Data Source: San Francisco Estuary Institute. http://www.sfei.org/grassland/reports/

Notes. (1) Includes 137 lbs of selenium released into Grassland wetland supply channels after January 1997 storms

(2) Includes 350 lbs of selenium released into Grassland wetland supply channels after February 1998 storms due to unforseen and uncontrollanble circumstances

Table 2. Monthly Selenium Discharges from the San Luis Drain (Station B) into Mud Slough Compared to Load Values, Pounds, October 1996 - December 2002

Calendar Year	1996		1997		1998		1999		2000		2001		2002	
	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge	Load Value	Actual Discharge
January			533	599	533	335	506	284	479	285	453	255	385	246
February			866	878	866	965	823	609	779	541	736	574	619	483
March			1,066	1,119	1,066	1,600	1,013	799	959	761	906	779	753	586
April			799	1,280	799	1,554	759	529	719	549	679	481	577	500
May			666	849	666	1,371	633	482	599	427	566	408	488	363
June			599	611	599	807	569	524	539	439	509	426	429	397
July			599	428	599	615	569	462	539	425	509	416	429	365
August			533	348	533	500	506	418	480	324	453	353	387	322
September			350	109	350	388	350	275	350	242	350	171	310	241
October	348	202	348	248	348	277	348	181	348	146	315	118	308	216
November	348	252	348	207	348	226	348	193	348	174	315	148	308	216
December	389	285	389	178	389	239	389	236	389	194	353	170	334	241
Total Discharge from San Luis Drain		739 (1)		6,854 (2)		8,877		4,992		4,507		4,299		4,176
Total Load Limitation	1,085		7,096		7,096		6,813		6,528		6,144		5,327	
Discharge as Percent of Total		68%		97%		125%		73%		69%		70%		78%

Data Source: San Francisco Estuary Institute http://www.sfei.org/grassland/reports/

Notes:
(1) Includes 137 lbs of selenium released into Grassland wetland supply channels after January 1997 storms
(2) Includes 350 lbs of selenium released into Grassland wetland supply channels after February 1998 storms due to unforseen and uncontrollanble circumstances

Table 3. Wet Year Selenium Load Values for the San Luis Drain (Station B), pounds, October 2001 - December 2009

	2001	2002	2003	2004	2005	2006	2007	2008	2009
January		385	359	333	289	211	211	211	211
February		619	571	523	440	297	297	297	297
March		753	685	618	496	297	297	297	297
April		577	538	499	433	315	315	315	315
May		488	464	439	400	322	322	322	322
June		429	397	365	308	212	212	212	212
July		429	397	365	310	214	214	214	214
August		387	363	339	299	225	225	225	225
September		310	303	297	291	264	264	264	264
October	315	308	301	294	260	260	260	260	260
November	315	308	301	294	260	260	260	260	260
December	353	334	316	298	211	211	211	211	211
Annual load value	983	5,328	4,665	4,662	3,996	3,088	3,088	3,088	3,088

Data Source: U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. September 28, 2001. Agreement for Use of the San Luis Drain for the Period October 1, 2001 through December 31, 2009. Agreement No. 01-WC-20-2075. Appendix C.

Table 4. Dry Year Selenium Load Values for the San Luis Drain (Station B), pounds, October 2001 - December 2009

	2001	2002	2003	2004	2005	2006	2007	2008	2009
January		385	359	333	289	211	211	198	185
February		619	571	523	440	297	297	265	234
March		753	685	618	496	297	297	265	233
April		577	538	499	433	315	315	282	249
May		488	464	439	400	322	322	288	255
June		429	397	365	308	212	212	188	165
July		429	397	365	310	214	214	188	166
August		387	363	339	299	225	225	190	175
September		310	303	297	291	264	264	200	193
October	315	308	301	294	260	260	260	229	190
November	315	308	301	294	260	260	260	225	190
December	353	334	316	298	211	211	211	198	185
Annual load value	983	5,328	4,995	4,662	3,996	3,088	3,088	2,754	2,421

Data Source: U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. September 28, 2001. Agreement for Use of the San Luis Drain for the Period October 1, 2001 through December 31, 2009. Agreement No. 01-WC-20-2075. Appendix C.

Table 5a. Salinity Load Values for the San Luis Drain (Station B), tons October 2001 - December 2005

	2001	2002	2003	2004	2005
January		11,935	11,338	10,741	10,526
February		20,924	19,877	18,831	18,455
March		24,208	22,998	21,788	21,352
April		20,015	19,014	18,014	17,653
May		20,021	19,020	18,019	17,659
June		20,624	19,593	18,562	18,191
July		21,862	20,769	19,676	19,283
August		18,396	17,476	16,556	16,225
September		10,210	9,700	9,189	9,006
October	6,423	6,423	6,102	5,781	5,665
November	7,036	7,036	6,684	6,332	6,205
December	8,646	8,646	8,214	7,782	7,626
Annual load value	22,105	190,301	180,786	171,271	167,845

Data Source: U S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority September 28, 2001. Agreement for Use of the San Luis Drain for the Period October 1, 2001 through December 31, 2009. Agreement No. 01-WC-20-2075. Appendix E.

Note: Salinity Load Values for 2006 - 2009 will be calculated based on Water Year hydrological conditions; the details are discussed in Appendix I of the 2001 Use Agreement

Table 5b. Salinity Discharge Goals for the San Luis Drain (Station B), tons October 2001-December 2005

	2001	2002	2003	2004	2005
January		9,548	8,951	8,354	8,139
February		16,739	15,693	14,647	14,270
March		19,367	18,156	16,946	16,510
April		16,012	15,011	14,011	13,650
May		16,017	15,016	14,015	13,655
June		16,500	15,468	14,437	14,066
July		17,490	16,397	15,304	14,910
August		14,716	13,797	12,877	12,546
September		8,168	7,658	7,147	6,963
October	5,138	5,138	4,817	4,496	4,381
November	5,629	5,629	5,277	4,925	4,798
December	6,917	6,917	6,485	6,052	5,897
Annual load value	17,684	152,241	142,726	133,211	129,785

Data Source: U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority September 28, 2001. Agreement for Use of the San Luis Drain for the Period October 1, 2001 through December 31, 2009. Agreement No. 01-WC-20-2075. Appendix E.

Note: Salinity Discharge Goals for 2006 - 2009 will be calculated based on Water Year hydrological conditions; the details are discussed in Appendix I of the 2001 Use Agreement.

Table 6. Grassland Bypass Project Monitoring Stations, Parameters, and Sampling Frequencies

Station / Site / Location		Flow	Temperature	pH	Electrical Conductivity	Total Suspended Solids	Selenium	Boron	Nutrients	Molybdenum	Sediment Quality	Sediment Quantity	Biota	Chronic and Acute Toxicity
San Luis Drain	A	C	C		C	W	W	W			A	A		
	B	**C**	C / **W**	**W**	C / **W**	**W**	**D**	**D / W**	**W / M (1)**	**W / M (1)**	A	A		M / **Q**
	checks 1-2										A	A		
	checks 10-11										A	A		
	checks 14-15										A	A		
	checks 17-18										A	A		
Mud Slough	C		**W**	**W**	**W**		**W**	**W**	**W / M (1)**	**W / M (1)**	Q		Q	M / **Q**
	D	**C**	**C**	**W**	**C**		**W**	**W**	**W / M (1)**	**W / M (1)**	Q		Q	M / **Q**
	E										Q		Q	
	I2		W	W	W		W	W			Q		Q	
Salt Slough	F	C	C	W	C		W	W			Q		Q	M / **Q**
Wetland Channels	J	D	W	W	W		W	W						
	K	D	W	W	W		W	W						
	L2	D	W	W	W		W	W						
	M2	D	W	W	W		W	W						
San Joaquin River	G	**C**	C / **W**	**W**	C / **W**	**W**	W	W	**W / M (1)**	**W / M (1)**			Q	
	H		W	W	W		W	W					Q	
	N	**C**	C / **W**	**W**	C / **W**	**W**	D	W	**W / M (1)**	**W / M (1)**				

Data Source: U.S. Bureau of Reclamation, et. al. June 2002. Monitoring Program for the Operation of the Grassland Bypass Project.

Notes:

Sampling Frequency C = Continuous Q = Quarterly
D = Daily A = Annually
W = Weekly M = Monthly

Letters in Bold indicate a monitoring requirement within Waste Discharge Requirement 5-01-234.

(1) Weekly sampling March through August, and Monthly sampling: September through February

Table 7a. San Joaquin River at Hills Ferry (Site H) Average Water Quality October 2001 - December 2002

Sample Date	Specific Conductance µmhos/cm	Selenium µg/L	Boron mg/L
Oct-2001	1,680	3.0	0.8
Nov-2001	1,610	2.5	1.0
Dec-2001	2,153	2.9	1.4
Jan-2002	1,816	3.3	1.2
Feb-2002	2,243	7.1	1.6
Mar-2002	2,360	7.0	1.8
Apr-2002	2,500	9.6	1.8
May-2002	2,223	7.5	1.5
Jun-2002	2,223	10.0	1.8
Jul-2002	1,758	7.0	2.1
Aug-2002	1,863	7.2	1.8
Sep-2002	1,780	6.1	1.3
Oct-2002	1,698	5.1	1.1
Nov-2002	1,618	3.5	1.1
Dec-2002	1,608	3.1	1.2
Maximum	2,840	13.2	3.8
Minimum	950	1.2	0.6
Average	1,931	5.7	1.4
Number of samples	61	61	61

Data Source: Samples collected by Grassland Area Farmers; analyses by South Dakota State University Olsen Laboratory.

Table 7b. San Joaquin River at Hills Ferry (Site H) Average Water Quality during Water Years 1997 – 2002

Water Year	Specific Conductance µmhos/cm	Selenium µg/L	Boron mg/L
WY 1997	1,543	6.8	1.3
WY 1998	1,021	3.1	0.8
WY 1999	1,531	5.0	1.3
WY 2000			
WY 2001	1,838	6.4	1.5
WY 2002	2,002	6.1	1.5

Data Sources: 1997 - 1999 averages calculated from weekly grab samples collected by the CVRWQCB at Station STC 521

No samples collected between October 1, 1999 to September 30, 2000

2001 - 2002 averages calculated from weekly grab samples collected by the Grassland Area Farmers (Site H)

Note: Water Year = October 1 - September 30

Table 7c. San Joaquin River at Hills Ferry (Site H) Average Water Quality during Calendar Years 1997 – 2002

	Specific Conductance µmhos/cm	Selenium µg/L	Boron mg/L
1997	1,695	7.0	1.4
1998	855	2.7	0.7
1999	1,725	6.0	1.4
2000	1,525	4.3	1.2
2001	1,924	6.1	1.5
2002	1,965	6.4	1.5

Data Sources: 1997 - 1999 averages calculated from weekly grab samples collected by the CVRWQCB at Station STC 521

2000 - 2002 averages calculated from weekly grab samples collected by the Grassland Area Farmers (Site H)

Figure 1. Map of the Grassland Bypass Project

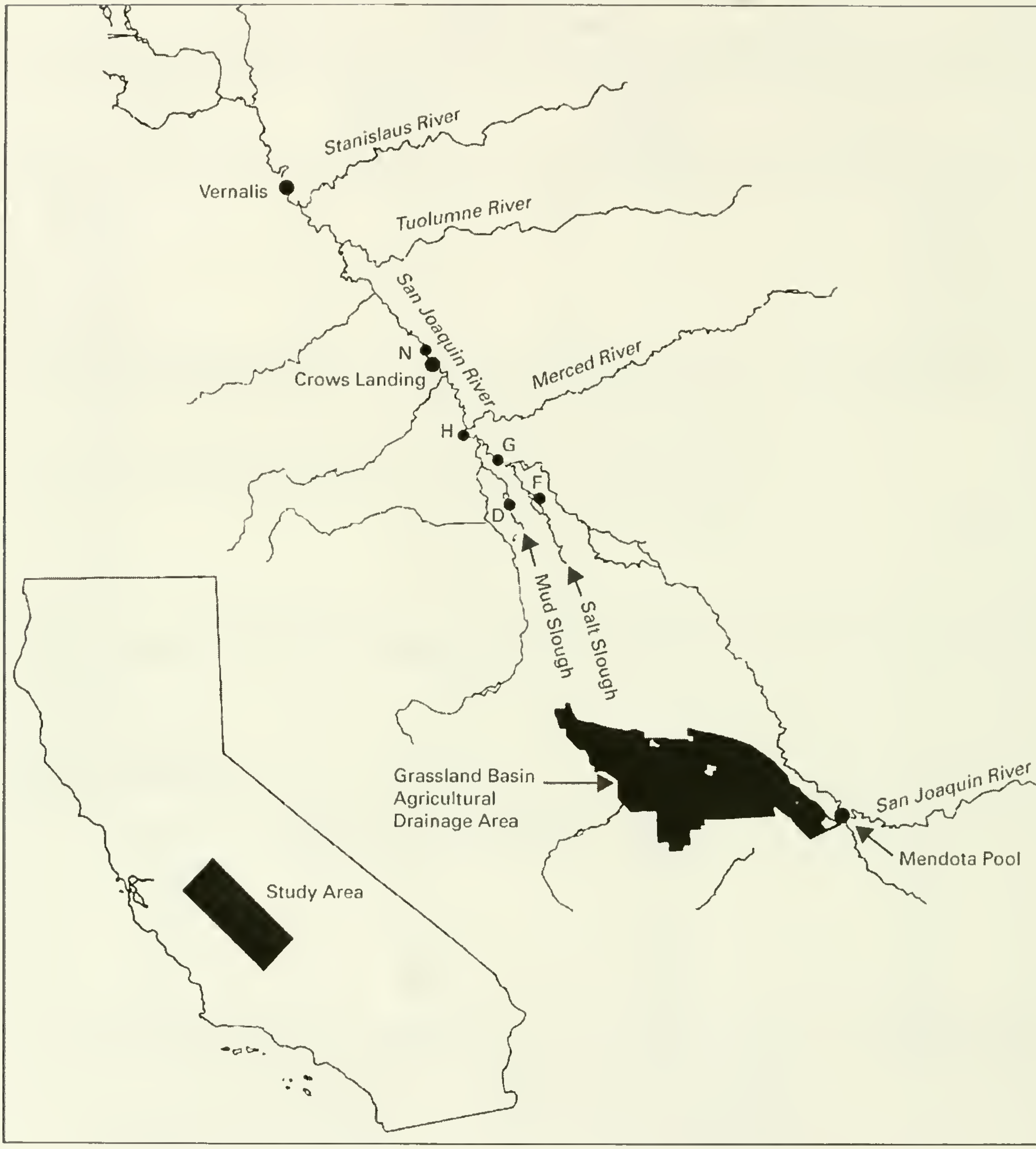


Figure 2. Schematic Diagram Showing Locations of GBP Monitoring Sites Relative to Major Hydrologic Features of the Study Area

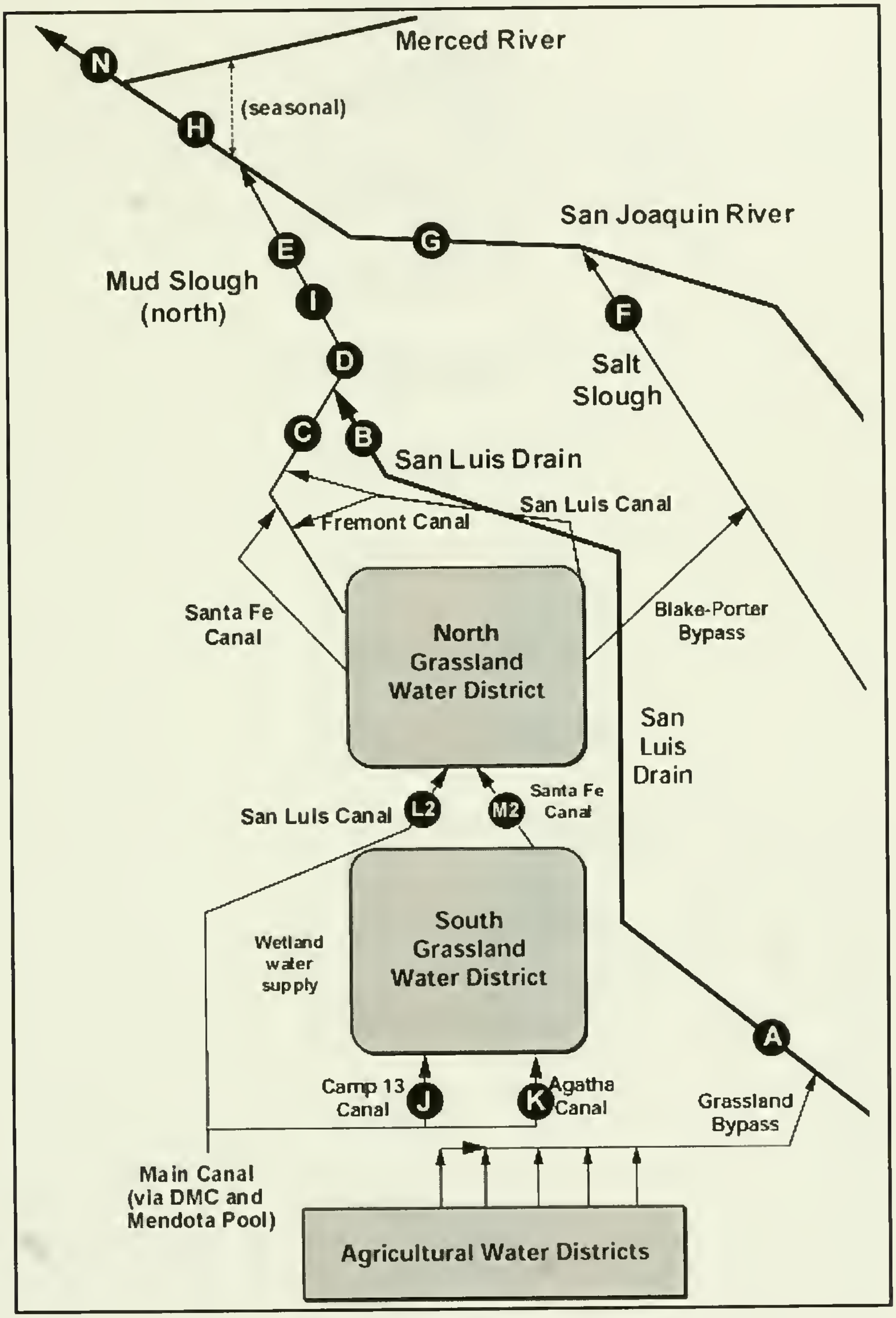
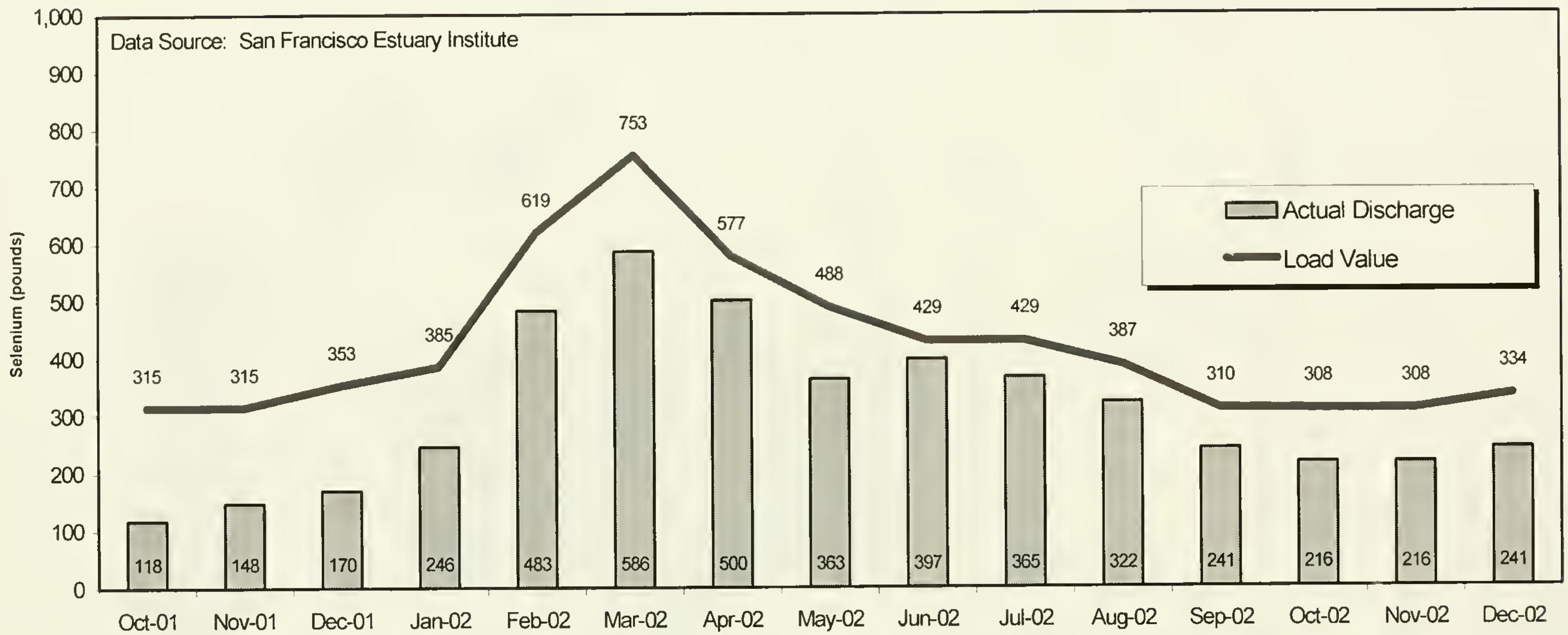


Figure 3. Grassland Bypass Project October 2001 - December 2002 Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values



2

Drainage Control Activities by the Grassland Area Farmers

October 1, 2001 – December 31, 2002

Joseph C. McGahan[1]

Grassland Bypass Project

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Introduction

The Grassland Area Farmers formed a regional drainage entity in March 1996 under the umbrella of the San Luis and Delta-Mendota Water Authority to implement the Grassland Bypass Project. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas (see Figure 1). Participants include the Broadview Water District, Charleston Drainage District, Firebaugh Canal Water District, Pacheco Water District, Panoche Drainage District, Widren Water District and the Camp 13 Drainage District (located in part of Central California Irrigation District). This entity includes approximately 97,000 gross acres of irrigated farmland on the Westside of the San Joaquin Valley, referred to as the Grassland Drainage Area. The area is highly productive, producing an estimated $113 Million annually in agricultural crop market value, with an additional estimated $126 Million generated for the local and regional economies, for a total estimated economic value of $239 Million.

The Grassland Area Farmers have implemented several activities aimed at reducing discharge of subsurface drainage waters to the San Joaquin River. These activities have included the Grassland Bypass Project and the San Joaquin River Water Quality Improvement Project. They also include: formation of a regional drainage entity, newsletters and other communication with the farmers, a monitoring program, using State Revolving Fund loans for improved irrigation systems, utilizing and installing drainage recycling systems to mix subsurface drainage water with irrigation supplies under strict limits, tiered water pricing and tradable loads programs.

Grassland Bypass Project

The Grassland Bypass Project is an innovative program that was designed to improve water quality in the channels used to deliver water to wetland areas. Prior to the Project, subsurface drainage water was conveyed through those channels in route to the San Joaquin River and limited their availability to deliver high-quality habitat supplies. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas. Figures 2A and 2B shows the discharge from the Grassland Bypass Project from WY 1997 through the end of calendar year 2002.

Negotiations between the San Luis & Delta-Mendota Water Authority and the U S Bureau of Reclamation to utilize a portion of the San Luis Drain for the Project commenced in 1988. Stakeholders included in the process were: U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, California Department of Fish and Game, the Central Valley Regional Water Quality Control Board, Environmental Defense, Contra Costa County and Contra Costa Water District. In late 1995, environmental documentation for the first five years was completed and the Use Agreement was signed. Discharge through the project began in September 1996. In September 2001, the Use Agreement was extended for another 8 years and 3 months (through December 2009). An Environmental Impact Report/Environmental Impact Statement was completed and on September 7, 2001 the Central Valley Regional Water Quality Control Board issued new Waste Discharge Requirements. Other items completed to support the continued use

were a Biological Assessment/Biological Opinion, a selenium Total Maximum Monthly Load (TMML) report submitted by the Regional Board to EPA and a continued monitoring program. The new Use Agreement contains continued reductions in selenium discharge until ultimately TMML limits are achieved in 2005 for above normal and wet years and continued progress is made to meet water quality objectives in 2010 for below normal, dry and critical years. The future load limits are shown on Figure 3.

The benefits of the Grassland Bypass Project are well documented. In water year (WY) 2002, drainage volume has been reduced 46%, selenium load has been reduced 61%, salt load has been reduced 41% and boron load has been reduced 34%, all from pre-project conditions in WY 1996 (see Table 1).

In WY 1996, prior to the Grassland Bypass Project, the mean selenium concentration in Salt Slough at Lander Avenue was 16 parts per billion (ppb). Since October 1996, the 2 ppb water quality objective for Salt Slough has been met in all months except one. The only month in which objectives were not met was February 1998 when uncontrollable flood flows were mixed with subsurface drainage water and could not be contained within the Grassland Bypass Project (that month the selenium concentration in Salt Slough was 4 ppb). In WY 1996 the mean selenium concentration at Camp 13 Ditch was 55.9 parts per billion (ppb). In WY 1997, the first year of operation of the Grassland Bypass Project, the mean selenium concentration at Camp 13 Ditch was 2.6 ppb. This value was slightly above the wetland selenium objective of 2 ppb. In April of 1998, specific actions were taken to eliminate any possible subsurface drainage discharges from the Grassland Drainage Area into the Camp 13 Slough and other discharge points. Since that time, there have been no discharges from the Grassland Drainage Area into wetland channels. However, the 2ppb monthly mean selenium objective was exceeded in wetland supply channels in WY 2003. A number of sources may contribute to the exceedance (see Chapter 4) and further investigations are underway.

San Joaquin River Water Quality Improvement Project

Funds provided from Proposition 13 allowed for the purchase and improvement of 4,000 acres of land within the Grassland Drainage Area as part of the San Joaquin River Water Quality Improvement Project (SJRIP) for the purpose of drain water disposal. The location of the SJRIP Project is shown in Figure 1 and the cropping details for WY 2002 are shown in Figure 4. The first phase of the SJRIP was implemented in the winter of WY 2001 with the planting of salt tolerant crops and construction of distribution facilities. Since the project's inception, the planted acreage has increased from the original 1,821 acres to more than 2,420 acres, which have been irrigated with drainage water or blended water. In 2002, more than 3,700 acre-feet of drain water was applied to the project, reusing more than 1,100 pounds of selenium, 17,700 tons of salt, and 77,000 pounds of boron (see Figure 5). Additionally, almost three miles of irrigation pipeline and 500 acres of subsurface drainage systems were installed in 2002 as part of the Grassland Integrated Drainage Management Project (funded by Proposition 13).

The SJRIP project is the key for the Grassland Drainage Area as a whole to meet future selenium load limits. This project will ultimately allow for planting and irrigation of the entire 4,000 acres with drainage water. Future phases call for acquisition of additional acreage,

installation of subsurface drainage systems and implementation of treatment and salt disposal components.

Other Activities

The Grassland Area Farmers and member districts are continuing advances into drainage management and disposal with the cooperation of federal and state agencies. Research is being undertaken in algal bacteria selenium treatment, reverse osmosis treatment, flow through selenium removal and individual district reuse projects. Continued funding is being sought for these activities. An estimate has been made of the components of subsurface drainage within the GDA. This information is shown in Figure 5.

Future regulations may include salt and boron discharge limits to the San Joaquin River. The Grassland Area Farmers are active participants in this process as well other regulatory efforts such as the dissolved oxygen issue in the San Joaquin River.

Table 1. Grassland Bypass Project
Summary of Annual Volumes and Loads

	WY 1996	WY 1997	WY 1998	WY 1999	WY 2000	WY 2001	WY 2002	% Reduction from 1996
Volume of Drainage Discharge (af)	53,000	39,860	49,244	32,310	31,260	28.254	28,391	46%
Selenium Load (lbs)	10,036	7,093	9,118	5,124	4,603	4,377	3,939	61%
Boron Load (lbs)	830,700	682,300	967,200	630,200	606,700	423,300	550,500	34%
Salt Load (tons)	197,500	172,600	213,500	149,100	135,000	120,000	116,100	41%

Note: WY 1997 and 1998 include discharges through wetlands channels.

Figure 1

Grassland Drainage Area
Location Map

Figure 2a. Discharge from the Grassland Bypass Project October 1996 – September 2001 (Phase I)

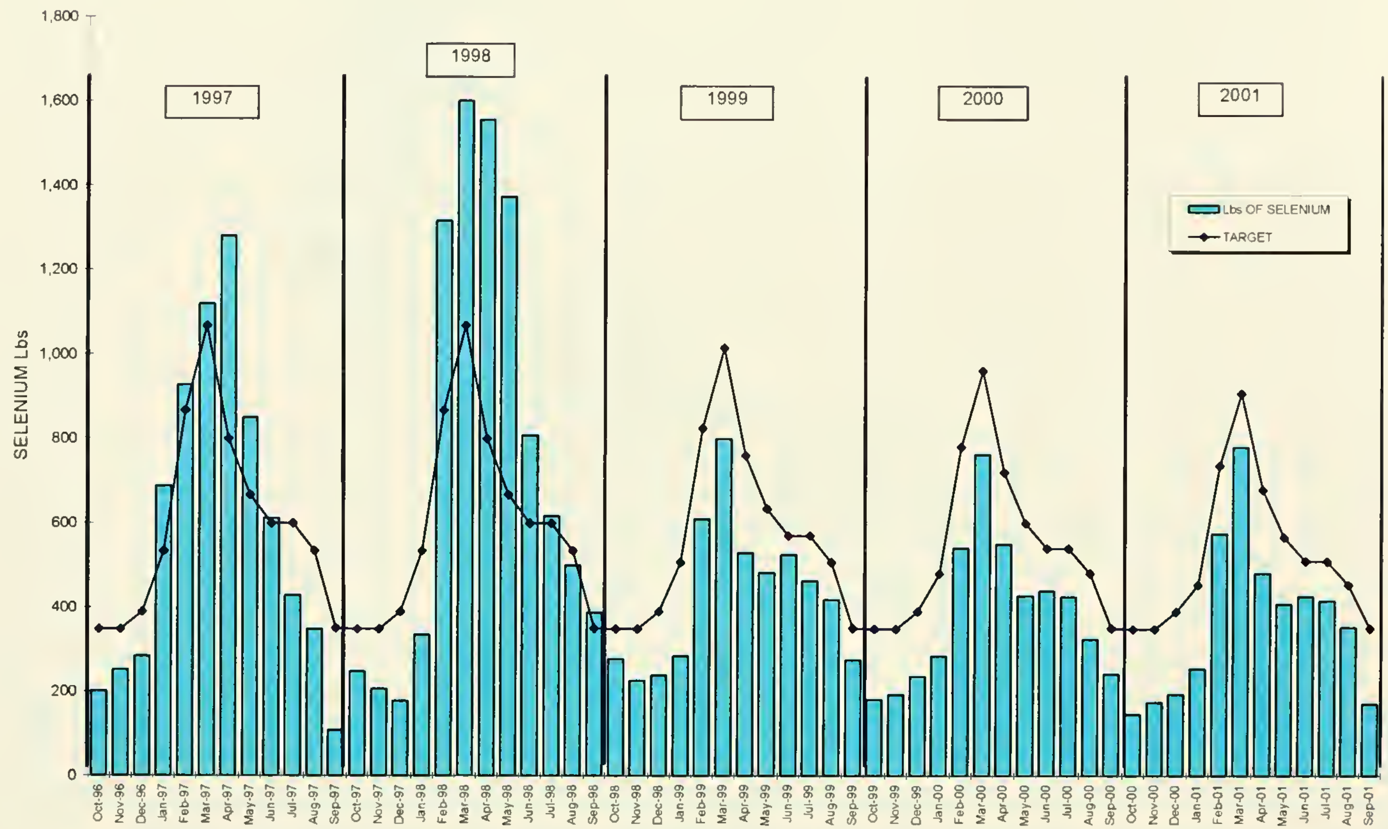


Figure 2b. Discharge for the Grassland Bypass Project October 2000 Through December 2002 (Phase II)

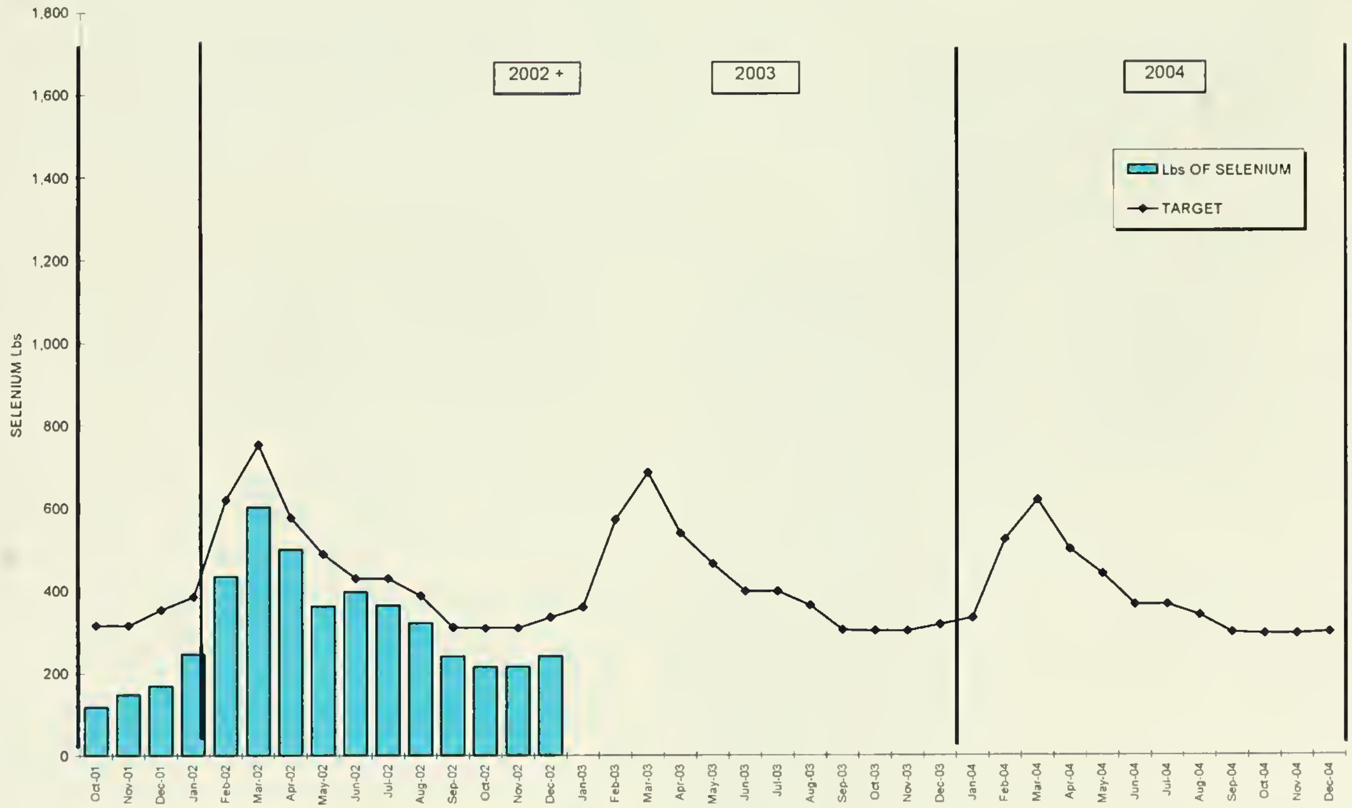
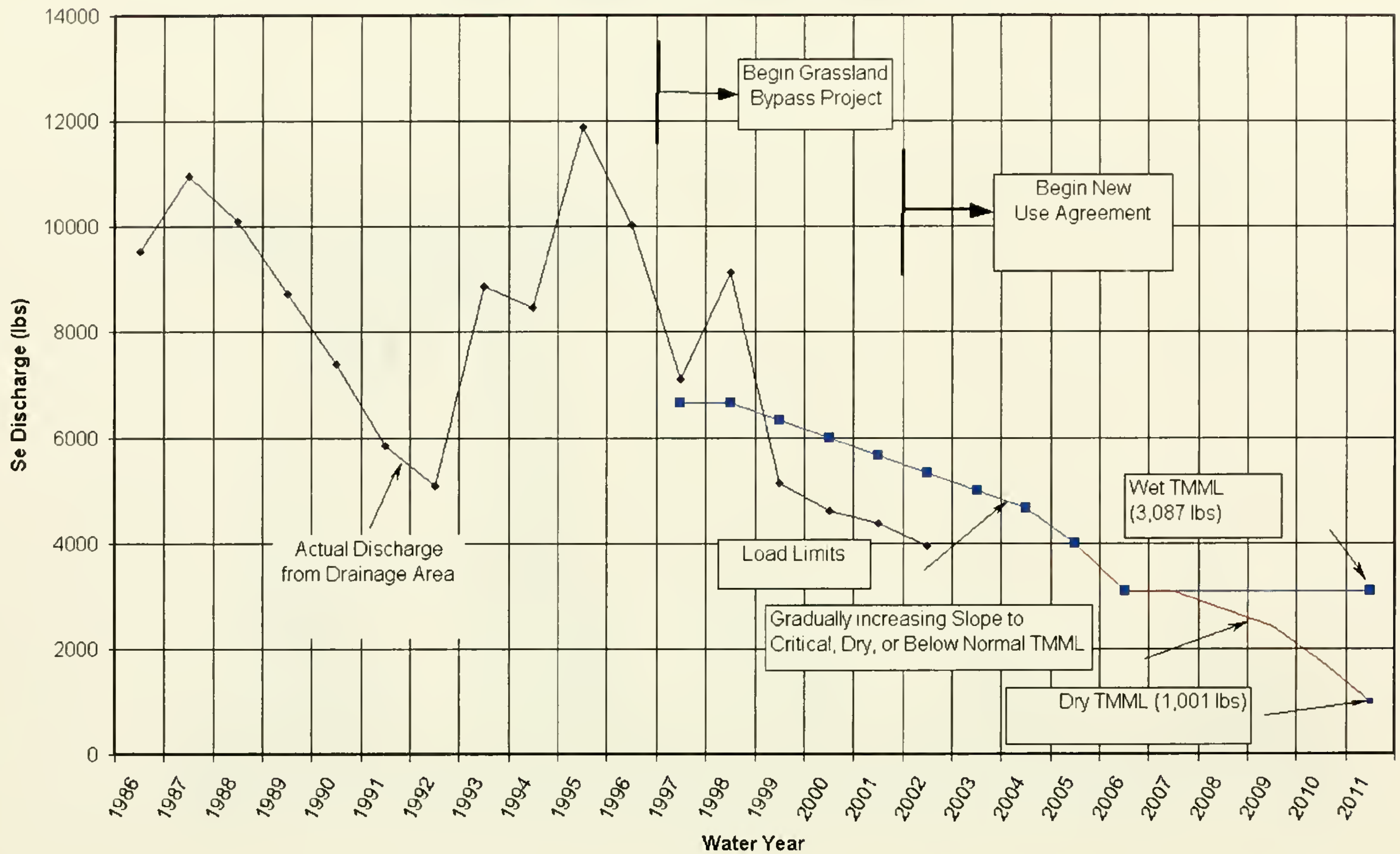


Figure 3. Grassland Drainage Area: Selenium Discharge and Targets



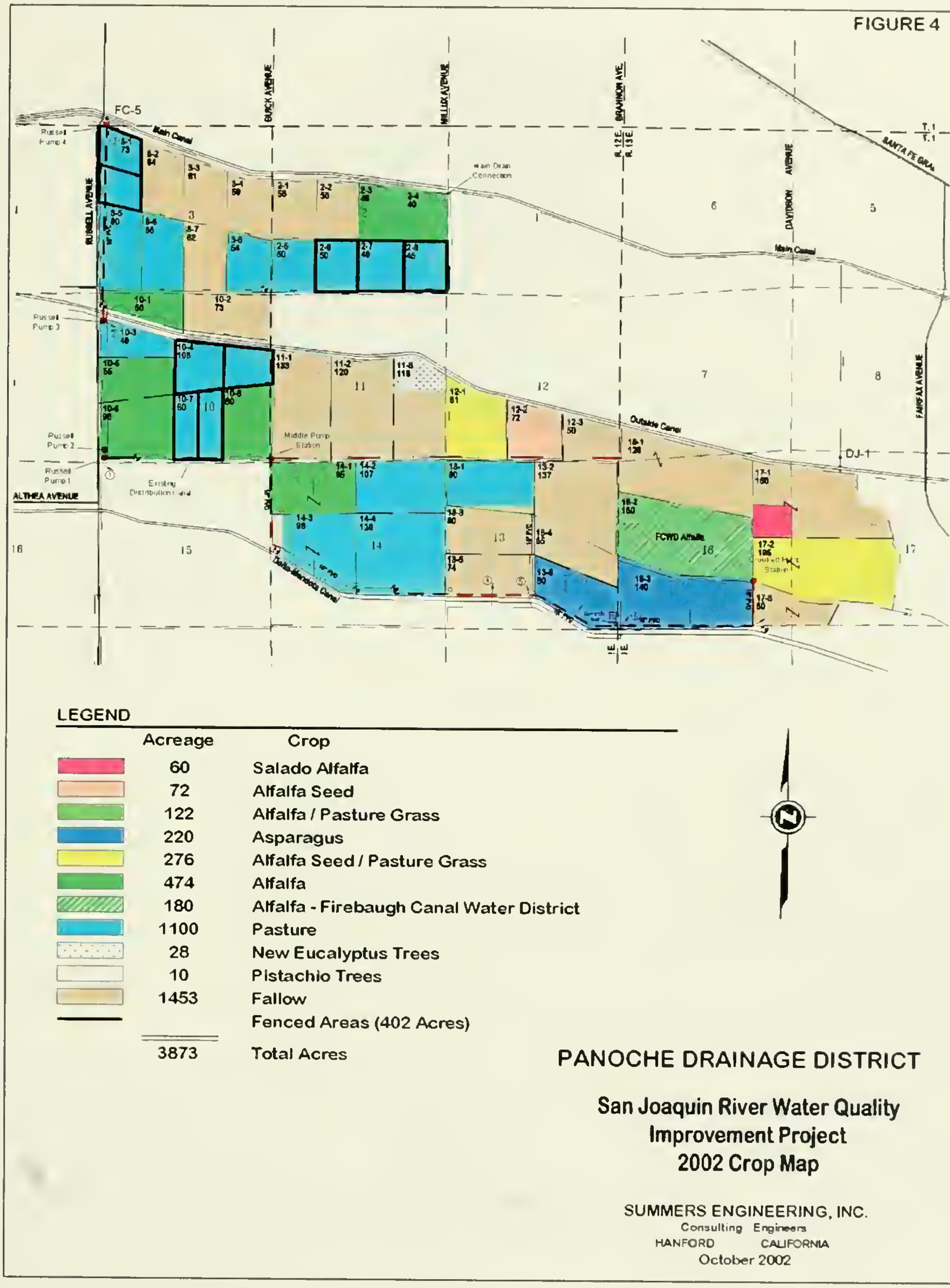
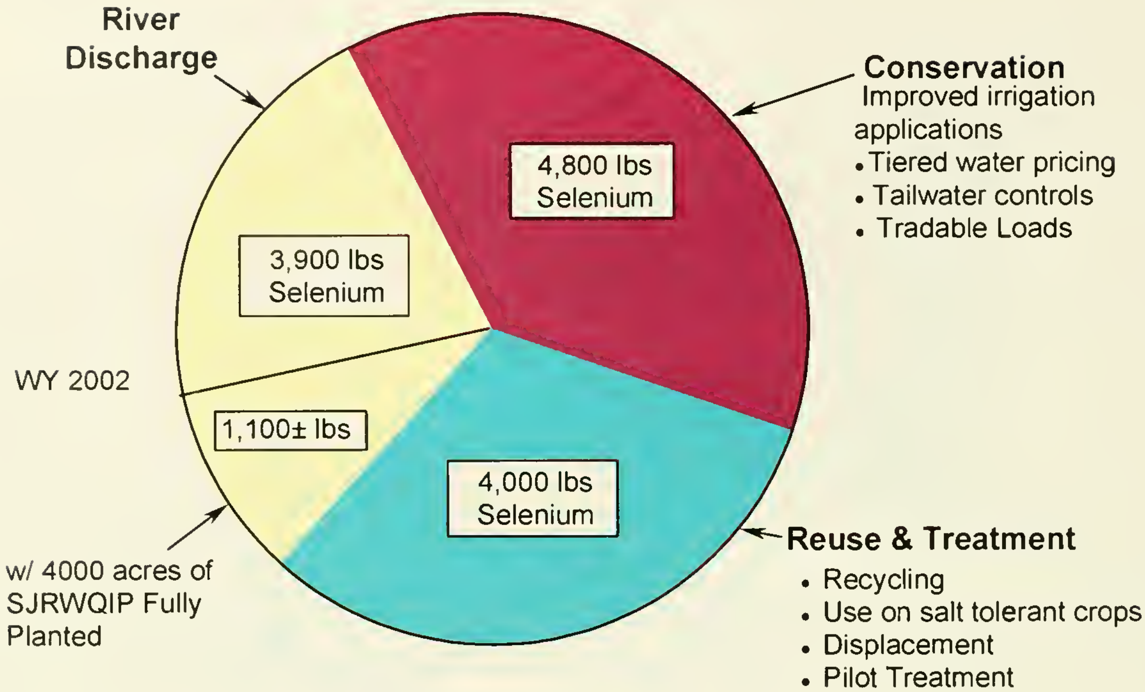


FIGURE 4
FC-5
RUSSELL AVENUE
BUCK AVENUE
MILLUX AVENUE
BRANNON AVE
DAYTOBON AVENUE
FAIRFAX AVENUE
ALTHEA AVENUE
SANTA FE GRADE
Main Canal
Outside Canal
DJ-1
Middle Pump Station
FCWD Alfalfa
LEGEND
Acreage Crop
60 Salado Alfalfa
72 Alfalfa Seed
122 Alfalfa / Pasture Grass
220 Asparagus
276 Alfalfa Seed / Pasture Grass
474 Alfalfa
180 Alfalfa - Firebaugh Canal Water District
1100 Pasture
28 New Eucalyptus Trees
10 Pistachio Trees
1453 Fallow
Fenced Areas (402 Acres)
3873 Total Acres
PANOCHE DRAINAGE DISTRICT
San Joaquin River Water Quality
Improvement Project
2002 Crop Map
SUMMERS ENGINEERING, INC.
Consulting Engineers
HANFORD CALIFORNIA
October 2002

Figure 5. Historic Drainage Water (lbs Selenium)
57,000 AF 12,700 lbs Se 240,000 Tons Salt



3

Flow and Salinity Monitoring

October 1, 2001 – December 31, 2002

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Grassland Bypass Project

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Summary

Flow and electrical conductivity (EC) were measured during the fifteen month reporting period (October 1, 2001 – December 31, 2002) to monitor the effects of the Grassland Bypass Project (GBP) on the San Luis Drain, Mud Slough, Salt Slough, and the San Joaquin River. The U.S. Geological Survey (USGS) measured flow and EC at five monitoring stations (B, D, F, G, and N). The San Luis & Delta-Mendota Water Authority (Authority) measured flow and EC at Station A. Flow at Site C is derived as the difference between flows passing Sites D and B. A new station was installed on the San Joaquin River at Fremont Ford (Site G) by the USGS.

The California Regional Water Quality Control Board, Central Valley Region (Regional Board), measured the EC of water quality samples collected at these seven sites and at six other sites where flow is not measured (C, H, J, K, L2, and M2). The San Francisco Estuary Institute compiled this information in monthly and quarterly reports.

Table 1 is a summary of sampling methods at Stations A, B, C, D, F, G, and N.

Tables 2 - 8 summarize a) monthly flows, EC measurements, and salt loads at the seven stations during the fifteen month reporting period and b) the annual averages and totals for the six years of the Project. Note that the historical salinity and load values have been updated and differ from the WY 1999 report and errata sheets.

Figure 1 shows the pattern of rainfall and discharge from the 97,000 acre Grassland Drainage Area (GDA). About 4.4 inches of rain fell on the GDA between November 2001 and April 2002, and about 2.6 inches fell during November and December 2002. Peak flow in the San Luis Drain during the fifteen month period was 70 cubic feet per second (cfs), well below the 150 cfs capacity of the SLD specified in the 2001 Use Agreement (Reclamation and SLDMWA 2001). No drain water was discharged from the Project into wetland water supply channels during the fifteen month period.

Figures 2 – 7 show the monthly flows and average EC of water that passed the seven stations.

The Regional Board has calculated factors to convert EC to TDS and these are listed in Table I.

The method for determining flow-weighted concentrations and calculating loads of salt are explained in Regional Board, 1998 (pp. 4 - 8).

Station A - San Luis Drain near South Dos Palos, California

Grassland Bypass Project Station A	
Location	San Luis Drain Check 17, near Dos Palos, California (USGS 11262890) (Regional Board MER562)
Responsibility	San Luis & Delta-Mendota Water Authority (Summers Engineering)
Parameters	Stage, electrical conductivity, temperature
Equipment	Sharp-crested weir, stilling well with a Stevens recorder and shaft encoder, staff gauge, weir stick; electrical conductivity/temperature sensor; data logger, telephone and modem; Sigma autosampler.

Description

Station A is located near South Dos Palos, California. Its purpose is to measure the volume and quality of agricultural drainwater from the GDA as it enters the San Luis Drain.

Data Summary

Tables 2a, 2b, and 2c summarize the flow and salinity of water that passed Station A during the six years of the Project.

During the fifteen month period, the average flow that passed Station A was 32 cfs. The flow reached a maximum of 70 cfs on March 18, 2002 and again on June 17, 2002. The average EC of water that passed the site was about 4,535 microSiemens per centimeter (µS/cm), with a brief peak on October 3, 2002 of 6,250 µS/cm. The load of salt discharged from the GDA during the fifteen month period was about 126,353 tons.

Station B - San Luis Drain near Gustine, California

Grassland Bypass Project Station B	
Location	San Luis Drain, near Gustine, California (USGS 11262895, Regional Board MER535)
Responsibility	US Geological Survey (flow, EC, temp), Regional Board (EC, water quality)
Parameters	Stage, velocity, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure sensor, 2 - acoustic velocity meters, monthly current meter readings, 2 - EC/temperature sensors, data logger, telephone and modem.

Description

Station B is located about 28 miles northwest of Station A, about 2 miles from the terminus of the Drain. It is the primary site for measuring the flow and selenium load discharged from the GDA into Mud Slough. The performance of the GBP to manage flows and selenium loads is assessed at this site.

Data Summary

Tables 3a, 3b, and 3c summarize the flow and salinity of water that passed Station B during the six years of the Project.

During the fifteen month period, the average flow that passed Station B was 36 cfs. The peak flow of 69 cfs occurred on March 19, 2002 and June 18-19, 2002, one day after similar peaks at Station A.

The maximum daily EC was 5,130 µS/cm on March 30 – April 1, 2002. The flow-weighted average EC was 4,116 µS/cm. About 132,400 tons of salt were discharged from the San Luis Drain into Mud Slough during the fifteen month period.

Station C - Mud Slough (north), upstream of drainage discharge

Grassland Bypass Project Station C	
Location	Mud Slough, approximately 1/2 mile upstream of San Luis Drain terminus (Regional Board MER536)
Responsibility	Regional Board
Parameters	Electrical conductivity, temperature, pH, boron
Equipment	None. Weekly grab samples are taken here

Description

Station C is located in Mud Slough upstream from the end of the San Luis Drain. Water at this monitoring station derives primarily from managed wetlands in the North and South Grassland Water District. Data collected at this site are considered a baseline for measuring the impact of the GBP on the slough. The Regional Board collected weekly water quality samples here.

Data Summary

Tables 4a, 4b, and 4c summarize the flow and salinity of water that passed Station C during the six years of the Project. Flow was not measured at this site, but was estimated as the difference between flows passing Stations D and B.

During the fifteen month period, the average flow rate was 81 cfs. Daily flows peaked on December 23, 2002, at 491 cfs after heavy rains (Figure 1), and minimal in July and August.

About 73,640 acre-feet of water passed this site during the fifteen month period. The salinity of water at this site was measured by the Regional Board in its weekly grab samples. The average EC of water at this site was 1,690 µS/cm. The highest EC was measured on April 11, 2002 at 3,820 µS/cm. About 114,820 tons of salt were dissolved in the water that passed this site during the fifteen month period.

Station D - Mud Slough near Gustine, California, downstream from the drainage discharge

Grassland Bypass Project Station D	
Location	Mud Slough near Gustine, California (USGS 11262900) (Regional Board MER542)
Responsibility	US Geological Survey (flow, EC, temp), Regional Board (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station D is located in Mud Slough downstream from the terminus of the SLD.

Data summary

Tables 5a, 5b, and 5c summarize the daily flow and salinity of water that passed Station D during the six years of the Project.

During the fifteen month period, approximately 109,750 acre-feet of water passed this site. The GBP contributed 38% of this flow. The average flow passing Station D was 117 cfs. Peak flow was 511 cfs on December 23, 2002, following heavy rains. The average EC of water passing this site was 2,691 µS/cm. Approximately 244,920 tons of salt flowed past this site, 59 percent coming from the GBP, during the fifteen month study period.

Station F - Salt Slough at Highway 165 (Lander Avenue)

Grassland Bypass Project Station F	
Location	Salt Slough at Highway 165 near Stevinson, California (USGS 11261100) (Regional Board MER531)
Responsibility	US Geological Survey
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station F is where flow and water quality are monitored in Salt Slough. The GBP has removed the GDA's agricultural drainage water contribution to this water body. The water in Salt Slough is largely derived from wetlands in the Los Banos Wildlife Area, and the San Luis National Wildlife Refuge Complex.

Data Summary

Tables 6a, 6b, and 6c summarize the daily flow and EC of water that passed Station F during the six years of the Project.

No agricultural drainage water from the GDA was diverted into Salt Slough during the fifteen month period. The average flow of water was 153 cfs. The peak flow of 485 cfs occurred on December 22, 2002 after heavy rains. The average EC of water was 1,443 µS/cm. About 187,786 tons of salt were dissolved in water that passed this site during the fifteen month period.

Station G - San Joaquin River at Fremont Ford, California

Grassland Bypass Project Station G	
Location	San Joaquin River at Fremont Ford, California (USGS 11261500) (Regional Board MER538)
Responsibility	US Geological Survey (flow, EC, temp), Regional Board (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, GOES transmitter.

Description

Station G is a new station located along the San Joaquin River at the Highway 140 bridge, about five miles northeast of Gustine, California. It is upstream from the confluence of the river and Mud Slough. This site is used to measure the baseline flows and quality of water in the river before it receives water from the GBP.

Data Summary

Tables 7a, 7b, and 7c summarize the mean daily flow and EC of water that passed Station G during the fifteen month period. Flow was not measured here between October 1997 and December 2001. The Regional Board collected water quality samples at this site each week during this period, and the monthly average EC data are summarized in Table 7.

During the fifteen month period, the average flow that passed this site was about 222 cfs. The maximum flow of 2,100 cfs occurred on January 5, 2002. The flow-weighted average EC of water was 1,478 µS/cm.

Performance flow, EC, and temperature measurements by the USGS commenced on December 5, 2001.

Station N - San Joaquin River at Crows Landing, California

Grassland Bypass Project Station N	
Location	San Joaquin River at Crows Landing, California (USGS 11274550) (Regional Board STC504)
Responsibility	US Geological Survey (flow, EC, temp), Regional Board (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station N is located at Crows Landing on the San Joaquin River, about ten miles downstream of the tributary of the Merced River.

Data Summary

Tables 8a, 8b, and 8c summarize the mean daily flow and EC of water that passed Station N during the six years of the Project.

During the fifteen month period, the average flow that passed this site was about 760 cfs. The maximum flow of 2,290 cfs occurred on January 6, 2002. The total amount of water that passed this site was about 686,120 acre-feet. The discharge from the GBP was about five percent of this flow. The flow-weighted average EC of water that passed Station N was 1,161 µS/cm. The load of salt in the water was about 648,000 tons during the fifteen month period. The discharge from the GBP was about 21 percent of the salt load measured at this site.

Performance

EC and temperature data were lost for 87 days during the fifteen month period because of vandalism. Data were lost for fifty-one consecutive days between January 23 and March 15, 2002. The Regional Board had similar problems with its autosampler on this site between October 19, 2001 and January 25, 2002. The salt load for February 2002 was estimated using USGS flows and Regional Board daily autosampler data.

Other Monitoring Stations

The Regional Board collected weekly water quality samples at Stations J, K, L2, and M2 (Camp 13, Agatha, San Luis, and Santa Fe Canals, respectively). The purpose of these sites is to ensure that no agricultural drainage water from the GDA enters wetland supply channels in Grasslands Water District. The EC of each sample was measured in the laboratory. Flow is estimated at these locations by Grasslands Water District staff.

Table 9 summarizes monthly average EC of water that passed these stations during the fifteen month period, and annual averages for the six years of the Project. The data shows an increase in salinity as water passes through the southern portion of Grassland Water District as measured at Sites J, K, and through the northern portion of Grassland Water District at Sites L, L2, M, and M2.

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San Francisco Estuary Institute, February 2003. Grassland Bypass Project Annual Report October 1, 2000 - September 30, 2001

U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. September 28, 2001. Agreement for Use of the San Luis Drain. Agreement No. 01-WC-20-2075.

Table 1. Summary of Flow and Salinity Monitoring

Station	Agency	Parameter	Sample frequency	EC to TDS Factor (b)
A	SLDMWA	Flow	Continuous	
	SLDMWA	EC	Continuous	0.74
	CVRWQCB	EC	Weekly composite of daily samples	
B	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.74
	CVRWQCB	EC	Daily composite samples	
C		Flow	Derived (a)	
	CVRWQCB	EC	Weekly grab	0.68
D	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.69
	CVRWQCB	EC	Weekly grab	
F	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.68
	CVRWQCB	EC	Weekly grab	
G	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.68
	CVRWQCB	EC	Weekly grab	
N	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.62
	CVRWQCB	EC	Daily composite samples	
	CVRWQCB	EC	Weekly grab	

Notes:

(a) Flow passing Station C is calculated as difference between flows at Stations D and B.

(b) CVRWQCB, 1998. Page 15; San Luis Drain factor revised 10/2000.

EC - Electrical Conductivity

TDS - Total Dissolved Solids

Table 2a. Monthly Flow and Salinity of Water Entering the San Luis Drain, (Station A), October 2001 – December 2002

	Flow		Salinity		
	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
Oct-2001	11	672	4,980	3,685	3,368
Nov-2001	13	749	4,460	3,300	3,362
Dec-2001	12	755	4,760	3,522	3,618
Jan-2002	22	1,323	4,820	3,567	6,419
Feb-2002	47	2,593	4,390	3,249	11,457
Mar-2002	52	3,182	4,630	3,426	14,826
Apr-2002	42	2,484	4,700	3,478	11,750
May-2002	42	2,588	4,430	3,278	11,538
Jun-2002	55	3,269	4,170	3,086	13,719
Jul-2002	53	3,230	3,910	2,893	12,710
Aug-2002	54	3,318	3,580	2,649	11,954
Sep-2002	28	1,658	4,350	3,219	7,258
Oct-2002	15	901	5,040	3,730	4,570
Nov-2002	15	865	4,870	3,604	4,240
Dec-2002	18	1,112	4,900	3,626	5,484
15 month average	32		4,533	3,354	
15 month total		28,700			126,275

Data sources: Flow and EC - San Luis & Delta-Mendota Water Authority (Summers Engineering)
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion: 0.74

Table 2b. Average Flow and Salinity at Station A, Water Years 1997 – 2002

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	52	37,786	4,477	3,313	176,433
WY 1998	61	43,550	4,625	3,423	195,263
WY 1999	42	30,470	4,821	3,567	143,705
WY 2000	40	29,350	4,478	3,314	129,368
WY 2001	37	27,005	4,634	3,429	125,394
WY 2002	36	25,822	4,432	3,279	111,981

Data sources: Grassland Bypass Project Annual Report 2000 - 2001

Table 2c. Average Flow and Salinity at Station A, 1997 – 2002

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
CY 1997	51	36,580	4,627	3,424	173,154
CY 1998	62	44,201	4,699	3,477	199,506
CY 1999	41	29,869	4,767	3,528	139,922
CY 2000	40	28,939	4,379	3,241	126,124
CY 2001	36	26,143	4,668	3,454	121,678
CY 2002	37	26,524	4,483	3,317	115,926

Data sources: Grassland Bypass Project Annual Report 2000 - 2001

Table 3a. Monthly Flow and Salinity of Water in the San Luis Drain (Station B), October 2001 – December 2002

	Flow		Salinity		
	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
Oct-2001	18	1,100	3,879	2,870	4,294
Nov-2001	22	1,320	3,782	2,799	5,024
Dec-2001	20	1,250	4,219	3,122	5,308
Jan-2002	27	1,660	4,287	3,172	7,162
Feb-2002	49	2,730	4,314	3,192	11,853
Mar-2002	55	3,370	4,391	3,249	14,892
Apr-2002	41	2,430	4,650	3,441	11,372
May-2002	43	2,640	4,171	3,087	11,082
Jun-2002	56	3,320	3,931	2,909	13,134
Jul-2002	53	3,260	3,886	2,876	12,749
Aug-2002	55	3,410	3,474	2,571	11,922
Sep-2002	32	1,910	3,843	2,844	7,387
Oct-2002	20	1,240	4,177	3,091	5,213
Nov-2002	19	1,150	4,182	3,095	4,840
Dec-2002	22	1,360	4,556	3,371	6,236
15 month average	35		4,116	3,046	
15 month total		32,150			132,468

Data sources: Flow and electrical conductivity - US Geological Survey Station No. 11262895
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion. 0 74

Table 3b. Average Flow and Salinity at Station B, Water Years 1997 - 2002

	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	52	37,549	4,257	3,150	167,739
WY 1998	64	45,940	4,439	3,284	205,104
WY 1999	45	32,310	4,650	3,441	149,133
WY 2000	43	31,260	4,301	3,183	134,994
WY 2001	39	28,254	4,202	3,110	120,008
WY 2002	39	28,400	4,069	3,011	116,180

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 3c. Average Flow and Salinity at Station B, Calendar Years 1997 – 2002

	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
CY 1997	52	37,478	4,354	3,222	169,236
CY 1998	64	46,240	4,563	3,377	208,884
CY 1999	45	32,250	4,532	3,354	146,530
CY 2000	42	30,210	4,189	3,100	128,576
CY 2001	39	28,014	4,200	3,108	119,266
CY 2002	39	28,480	4,155	3,075	117,842

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 4a. Monthly Flow and Salinity of Water in Mud Slough Upstream of Drainage Discharge (Station C), October 2001 - December 2002

	Estimated Flow (*)		Salinity		
	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
Oct-2001	106	6,529	1,224	832	7,391
Nov-2001	148	8,778	1,383	940	11,227
Dec-2001	110	6,792	1,853	1,260	11,639
Jan-2002	124	7,599	1,968	1,338	13,830
Feb-2002	100	5,549	2,177	1,480	11,172
Mar-2002	84	5,179	2,765	1,880	13,243
Apr-2002	16	950	2,383	1,620	2,094
May-2002	21	1,321	1,861	1,265	2,274
Jun-2002	16	978	1,403	954	1,269
Jul-2002	21	1,274	2,177	1,480	2,565
Aug-2002	15	892	971	660	801
Sep-2002	17	1,037	1,061	721	1,018
Oct-2002	78	4,792	1,056	718	4,680
Nov-2002	136	8,057	1,435	976	10,692
Dec-2002	226	13,877	1,627	1,106	20,880
15 month average	81		1,690	1,149	
15 month total		73,604			114,773

Data sources	Flow - Calculated difference between Stations B and D.
EC - California Regional Water Quality Control Board, Site MER536
Total acre-feet, TDS, and salt load - calculated

Note	EC - TDS conversion	0.68

Table 4b. Average Flow and Salinity at Station C, Water Years 1997 - 2002

	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	129	93,381	1,300	884	99,334
WY 1998	193	136,640	1,185	806	146,403
WY 1999	96	69,050	1,427	970	90,132
WY 2000	87	63,180	1,455	990	84,197
WY 2001	90	64,617	1,696	1,153	92,674
WY 2002	65	46,878	1,769	1,203	78,521

Data source	Grassland Bypass Project Annual Report 2000 - 2001.

Table 4c. Average Flow and Salinity at Station C, Calendar Years 1997 - 2002

	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
CY 1997	122	87,972	1,380	939	103,057
CY 1998	193	137,080	1,127	766	139,962
CY 1999	92	66,490	1,457	991	89,568
CY 2000	91	65,862	1,446	983	86,603
CY 2001	84	60,874	1,778	1,209	95,993
CY 2002	71	51,505	1,740	1,183	84,517

Data source	Grassland Bypass Project Annual Report 2000 - 2001.

Table 5a. Monthly Flow and Salinity of Water in Mud Slough Downstream of Drainage Discharge (Station D), October 2001 - December 2002

	Flow		Salinity		
	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
Oct-2001	124	7,629	1,572	1,085	11,254
Nov-2001	170	10,098	1,660	1,145	15,730
Dec-2001	131	8,041	2,056	1,419	15,514
Jan-2002	151	9,259	2,430	1,677	21,113
Feb-2002	149	8,279	2,870	1,980	22,297
Mar-2002	139	8,549	3,430	2,367	27,517
Apr-2002	57	3,380	4,130	2,850	13,100
May-2002	64	3,961	3,480	2,401	12,935
Jun-2002	72	4,298	3,560	2,456	14,358
Jul-2002	74	4,534	3,190	2,201	13,573
Aug-2002	70	4,302	3,080	2,125	12,434
Sep-2002	50	2,947	2,840	1,960	7,854
Oct-2002	98	6,032	2,160	1,490	12,227
Nov-2002	155	9,207	1,900	1,311	16,416
Dec-2002	248	15,237	2,000	1,380	28,597
15 month average:	117		2,691	1,856	
15 month total:		105,753			244,918

Data sources: Flow and electrical conductivity - US Geological Survey Station No. 11262900
Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion: 0.69

Table 5b. Average Flow and Salinity at Station D, Water Years 1997 - 2002

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
WY 1997	181	130,930	2,390	1,649	254,022
WY 1998	257	182,580	2,600	1,794	369,564
WY 1999	141	101,360	2,582	1,781	229,871
WY 2000	131	94,440	2,496	1,722	201,601
WY 2001	129	92,871	2,769	1,910	214,420
WY 2002	104	75,277	2,858	1,972	187,679

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 5c. Average Flow and Salinity at Station D, Calendar Years 1997 - 2002

	Average cfs	Total acre-feet	Electrical conductivity µS/cm	Total dissolved solids mg/L	Salt load tons
CY 1997	174	125,450	2,471	1,705	256,897
CY 1998	258	183,320	2,559	1,766	365,813
CY 1999	137	98,740	2,589	1,786	225,749
CY 2000	133	96,072	2,471	1,705	201,846
CY 2001	123	88,887	2,796	1,930	216,029
CY 2002	111	79,985	2,923	2,017	202,420

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 6a. Monthly Flow and Salinity of Water in Salt Slough (Station F) October 2001 - December 2002

	Flow		Salinity		
	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	μS/cm	mg/L	tons
Oct-2001	95	5,833	1,402	953	7,563
Nov-2001	147	8,773	1,449	985	11,756
Dec-2001	126	7,765	1,757	1,195	12,617
Jan-2002	125	7,629	2,040	1,387	14,393
Feb-2002	185	10,197	1,540	1,047	14,522
Mar-2002	274	16,770	1,730	1,176	26,830
Apr-2002	155	9,160	1,620	1,102	13,723
May-2002	128	7,797	1,460	993	10,528
Jun-2002	141	8,349	1,220	830	9,420
Jul-2002	152	9,330	1,050	714	9,060
Aug-2002	136	8,349	1,030	700	7,953
Sep-2002	83	4,921	1,220	830	5,552
Oct-2002	103	6,319	1,280	870	7,480
Nov-2002	189	11,264	1,390	945	14,480
Dec-2002	261	16,227	1,460	993	21,910
15 month average	153		1,443	981	
15 month total		138,683			187,786

Data sources: Flow and electrical conductivity - US Geological Survey Station No 11361100

Total acre-feet, TDS, and salt load - calculated

Note: EC - TDS conversion 0 68

Table 6b. Average Flow and Salinity at Station F, Water Years 1997 – 2002

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	μS/cm	mg/L	tons
WY 1997	216	156,091	1,295	880	192,670
WY 1998	273	196,090	1,387	943	258,123
WY 1999	211	151,767	1,192	811	171,743
WY 2000	195	141,061	1,314	894	170,851
WY 2001	185	133,892	1,350	918	168,735
WY 2002	146	104,873	1,460	993	143,917

Data source. Grassland Bypass Project Annual Report 2000 - 2001

Table 6c. Average Flow and Salinity at Station F, Calendar Years 1997 – 2002

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	μS/cm	mg/L	tons
CY 1997	205	147,946	1,356	922	187,890
CY 1998	280	201,357	1,292	879	254,652
CY 1999	205	147,390	1,255	853	172,107
CY 2000	194	140,372	1,284	873	168,708
CY 2001	181	131,118	1,399	951	170,343
CY 2002	161	116,312	1,420	966	155,851

Data source Grassland Bypass Project Annual Report 2000 - 2001.

Table 7a. Monthly Flow and Salinity of Water in San Joaquin River, Fremont Ford (Station G), October 2001 - December 2002

	Flow		Salinity		
	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
Oct-2001	na	na	1,710	1,163	na
Nov-2001	na	na	1,650	1,122	na
Dec-2001	185	11,360	1,481	1,007	15,559
Jan-2002	539	33,168	852	579	26,134
Feb-2002	250	13,871	1,602	1,089	20,550
Mar-2002	329	20,210	1,860	1,265	34,764
Apr-2002	189	11,260	1,945	1,323	20,254
May-2002	149	9,130	1,725	1,173	14,565
Jun-2002	150	8,920	1,400	952	11,549
Jul-2002	162	9,935	1,183	804	10,869
Aug-2002	152	9,372	1,204	819	10,435
Sep-2002	102	6,040	1,315	894	7,345
Oct-2002	107	6,661	1,502	1,021	9,252
Nov-2002	209	12,266	1,492	1,015	16,925
Dec-2002	368	22,271	1,253	852	25,807
15 month average	222		1,478	1,005	
15 month total		na			na

Data sources — Flow and electrical conductivity - US Geological Survey Station No. 11261500
Total acre-feet, TDS, and salt load - calculated by USBR

Notes — EC - TDS conversion 0.68
New Station installed by USGS December 2001.
October and November EC and TDS calculated from CVRWQCB weekly grab data

Table 7b. Average Flow and Salinity at Station G, Water Years 1997 – 2002

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	na	na	1,047	712	na
WY 1998	na	na	703	478	na
WY 1999	na	na	1,138	774	na
WY 2000	na	na	1,321	898	na
WY 2001	na	na	1,514	1,029	na
WY 2002	221	133,266	1,494	1,016	172,025

Data source — Grassland Bypass Project Annual Report 2000 - 2001

Note — 1997 - 2001 electrical conductivity and TDS calculated from weekly samples collected by the Regional Board

Table 7c. Average Flow and Salinity at Station G, Calendar Years 1997 – 2002

	Average	Total	Electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
CY 1997	na	na	1,202	817	na
CY 1998	na	na	512	348	na
CY 1999	na	na	1,342	913	na
CY 2000	na	na	1,285	874	na
CY 2001	na	na	1,558	1,060	na
CY 2002	226	163,104	1,444	982	208,450

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 8a. Monthly Flow and Salinity of Water in the San Joaquin River at Crows Landing (Station N), October 2001 - December 2002

	Flow		Salinity		
	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
Oct-2001	742	45,632	768	476	29,550
Nov-2001	990	58,918	805	499	39,992
Dec-2001	949	58,325	1,016	630	49,967
Jan-2002	1,195	73,507	945	* 586	58,572
Feb-2002	798	44,321	1,558	* 966	58,225
Mar-2002	865	53,186	1,731	* 1,073	77,629
Apr-2002	699	41,598	1,347	835	47,247
May-2002	985	57,543	818	507	39,690
Jun-2002	492	30,054	1,407	872	35,656
Jul-2002	414	25,482	1,436	890	30,855
Aug-2002	409	25,141	1,390	862	29,466
Sep-2002	340	20,256	1,205	747	20,581
Oct-2002	630	38,744	813	504	26,560
Nov-2002	820	48,671	1,072	665	43,994
Dec-2002	1,050	64,739	1,099	681	59,992
15 month average	759		1,161	720	
15 month total		686,117			647,975

Data sources	Flow and electrical conductivity - US Geological Survey Station No 11274550
	Total acre-feet, TDS, and salt load - calculated
Note	EC - TDS conversion: 0.62
	No USGS EC data collected between January 23 and March 15, 2002 due to equipment failure
	* - CVRWQCB daily autosampler data used to replace missing USGS data

Table 8b. Average Flow and Salinity at Station N, Water Years 1997 – 2002

	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
WY 1997	5,408	3,844,270	820	508	1,080,703
WY 1998	6,868	4,904,910	601	373	1,511,470
WY 1999	1,412	1,015,350	902	559	680,098
WY 2000	1,417	1,027,480	976	605	703,876
WY 2001	903	653,425	1,185	734	623,555
WY 2002	712	556,214	1,212	752	542,457

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 8c. Average Flow and Salinity at Station NF, Calendar Years 1997 – 2002

	Average	Total	Flow-weighted electrical conductivity	Total dissolved solids	Salt load
	cfs	acre-feet	µS/cm	mg/L	tons
CY 1997	5,063	3,590,370	975	604	1,072,468
CY 1998	7,086	5,064,280	453	281	1,516,097
CY 1999	1,206	864,520	1,017	631	664,465
CY 2000	1,460	1,059,222	905	561	689,512
CY 2001	882	638,208	1,174	728	623,841
CY 2002	725	523,242	1,235	766	528,466

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 9a. Electrical Conductivity of Water in Grassland Wetland Supply Channels (October 2001 - December 2002)

GBP Station	H	J	K	L	L2	M	M2
Location	San Joaquin River at Hills Ferry	Camp 13	Agatha Canal	San Luis Canal	San Luis Canal, d/s of Splits	Santa Fe Canal	Santa Fe Canal, d/s of Splits
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
Oct-2001	1,680	676	656		851		882
Nov-2001	1,610	600	622		1,257		1,038
Dec-2001	2,153	678	833		1,508		1,413
Jan-2002	1,798	656	707		1,616		1,552
Feb-2002	2,243	723	830		977		1,583
Mar-2002	2,360	983	2,380		961		2,350
Apr-2002	2,500	1,181	2,070		927		1,850
May-2002	2,223	592	544		830		1,113
Jun-2002	2,223	738	560		658		1,242
Jul-2002	1,758	439	429		852		1,125
Aug-2002	1,863	659	556		1,210		1,260
Sep-2002	1,780	722	633		819		1,074
Oct-2002	1,698	732	649		695		886
Nov-2002	1,618	653	627		1,076		n/a
Dec-2002	1,608	807	648		1,110		n/a
15 month average	1,941	723	850		1,023		1,336

Data source: Electrical conductivity calculated from weekly grab samples collected by the Regional Board

Notes: Site H averages calculated from weekly grab samples collected by the Grassland Area Farmers.

Table 9b. Average Electrical Conductivity of Water in Grassland Wetland Supply Channels, Water Years 1997 – 2002

GBP Station	H	J	K	L	L2	M	M2
Location	San Joaquin River at Hills Ferry	Camp 13	Agatha Canal	San Luis Canal	San Luis Canal, d/s of Splits	Santa Fe Canal	Santa Fe Canal, d/s of Splits
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
WY 1997	1379	835	572	934.9		933.7	
WY 1998	1,021	1,424	969	1,214		1,284	
WY 1999	1,550	522	597		738		1,302
WY 2000	na	667	583		925		1,359
WY 2001	1,965	640	714		1,190		1,281
WY 2002	2,016	721	902		1,039		1,373

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Notes: Site H averages for 1997 - 1999 were calculated from weekly grab samples collected by the Regional Board

Site H 2001 - 2002 averages calculated from weekly grab samples collected by the Grassland Area Farmers.

Table 9c. Average Electrical Conductivity of Water in Grassland Wetland Supply Channels, Calendar Years 1997 – 2002

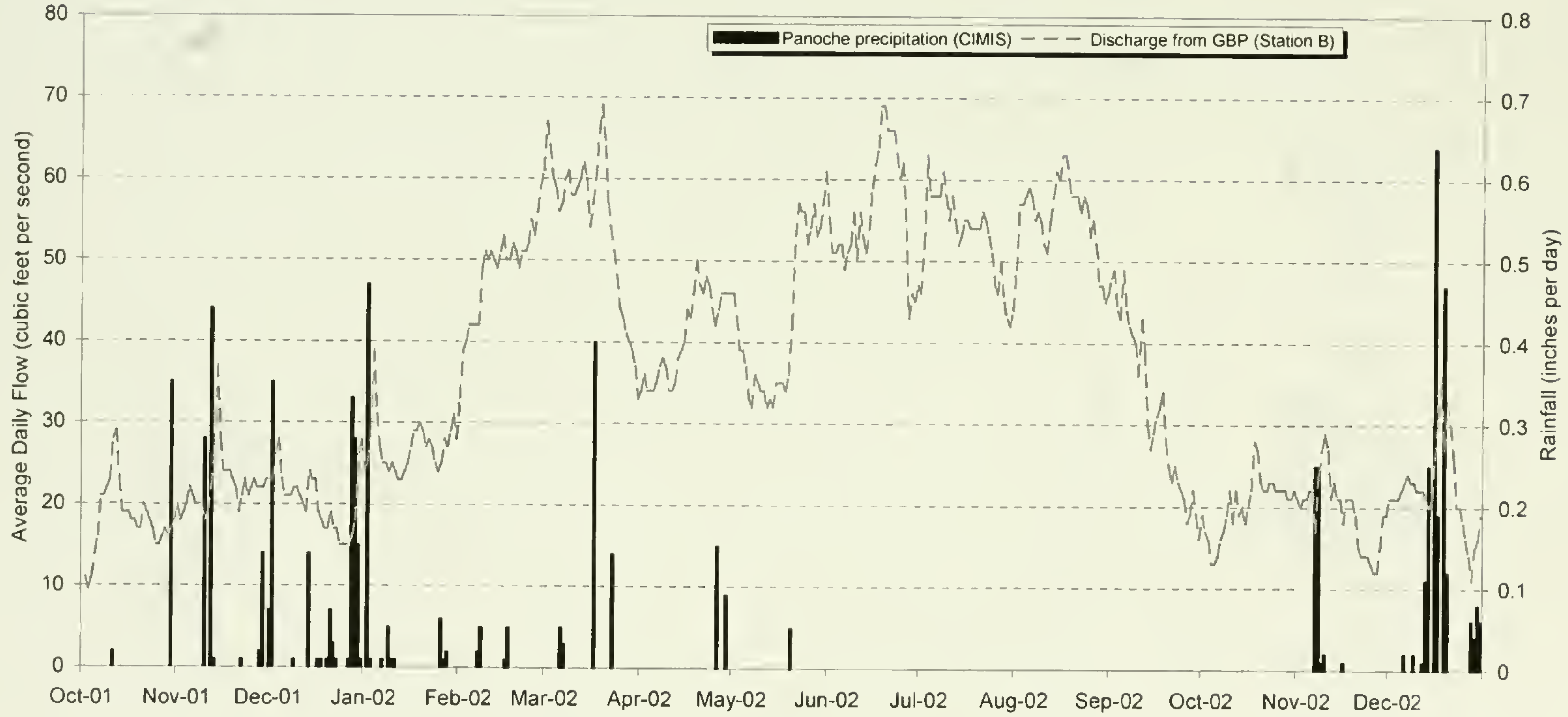
GBP Station	H	J	K	L	L2	M	M2
Location	San Joaquin River at Hills Ferry	Camp 13	Agatha Canal	San Luis Canal	San Luis Canal, d/s of Splits	Santa Fe Canal	Santa Fe Canal, d/s of Splits
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
CY 1997	1,520	1,040	615	997		1,079	
CY 1998	852	1,168	879	1,165		1,283	
CY 1999	1,673	630	686		829		1,356
CY 2000	na	632	558		1,168		1,276
CY 2001	1,927	657	751		1,064		1,331
CY 2002	1,973	740	886		978		1,404

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Notes: Site H averages for 1997 - 1999 were calculated from weekly grab samples collected by the Regional Board.

Site H 2001 - 2002 averages calculated from weekly grab samples collected by the Grassland Area Farmers.

Figure 1. Daily Rainfall and Discharge from the Grassland Bypass Project, October 2001 - December 2002



4

Water Quality Monitoring

October 1, 2001 – December 31, 2002

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Introduction

The monitoring program for the Grassland Bypass Project (GBP), including water quality monitoring, is described in detail in Compliance Monitoring Program for the Use and Operation of the Grassland Bypass Project, Phase II (USBR et al., 2002). This chapter provides a summary of the water quality monitoring program, modifications to the plan for the first 15 months of operation of Phase II of the GBP (October 1, 2001 to December 31, 2002), and water quality trends observed during the 15-month period. Detailed water quality data of individual monitoring stations will not be provided in this summary, as the San Francisco Estuary Institute (SFEI) has presented this information in another report (SFEI, 2003).

Monitoring Program

The Central Valley Regional Water Quality Control Board (CVRWQCB) has an on-going water quality monitoring program related to regulatory activities for agricultural subsurface drainage from the Grassland watershed. The water quality monitoring program for the GBP is an adaptation of the CVRWQCB monitoring program. The CVRWQCB conducts most of the water quality sampling, with assistance from the Panoche Water District (under contract with the San Luis & Delta-Mendota Water Authority; SL&D-MWA). The Panoche Water District collects samples at Stations A, J, K, L2, and M2. Samples are transferred to and processed by the CVRWQCB and analyzed by its contract laboratories. The CVRWQCB conducts quality assurance (QA) reviews of the data before submitting them to the SFEI for reporting. However, all CVRWQCB data are provisional and subject to change until the CVRWQCB approves its annual agency report on monitoring results for the 15-month period.

Monitoring Objectives

The water quality monitoring program was designed to provide data for evaluating compliance with commitments in the Project Waste Discharge Requirements, the Use Agreement, and associated documents. The commitments include:

- Monthly and annual selenium load limits on discharges
- No degradation of the San Joaquin River water quality relative to the pre-Project-condition
- Cessation of discharge of agricultural subsurface drainage to the wetland channels
- Management of flows in the San Luis Drain (SLD) so as to not mobilize channel sediments

The Monitoring Program was also designed to verify the validity of assumptions expressed in documents associated with the GBP. The assumptions include:

- The GBP is expected to result in selenium concentrations less than 2 μg/L in approximately 93 miles of wetland water supply channels.
- The increased frequency of exceeding selenium water quality objectives in Mud Slough (north) will be offset by a reduction of exceedances in Salt Slough.

In addition, the Monitoring Program was intended to provide data to be used to assess spatial and temporal trends in water quality parameters of concern and to characterize habitats in which biological samples were collected.

Sampling Locations

Monitoring was conducted in four areas; the SLD, Mud Slough (north), the San Joaquin River, and the Grassland wetland water supply channels, including Salt Slough. Table 1 summarizes the Monitoring Program, and sampling locations are depicted in Figure 2 in Chapter 1.

Frequency of Sampling

The frequency of sampling is outlined in Table 1. Weekly composite samples were collected at Station A (inflow to the SLD). Daily composite samples were collected at Station B (discharge from the SLD), and at Station N (San Joaquin River at Crows Landing). At Station A, daily samples were composited into a weekly sample to be used along with continuous flow data to calculate weekly selenium load inflow to the SLD. At Station B, daily composite samples along with continuous flow data were used to calculate daily selenium load discharge to Mud Slough (north). At Station N, daily composite samples were collected to allow the CVRWQCB to calculate loads and evaluate progress toward compliance with Basin Plan water quality objectives. The compliance date at Station N for the selenium water quality objective (5 µg/L 4-day average) during normal and wet years is October 1, 2005, and during critical years is October 1, 2010 (CVRWQCB, 1998a) (Table 2). Since the objective is based on a 4-day average concentration, consecutive daily samples are required at this station. The remaining stations were sampled on a weekly basis.

Sampling Methodology

Three types of sampling techniques were utilized, depending on the frequency of sampling and data needs: auto-sampler, mid-channel depth-integrated, and grab sample from channel bank. Auto-samplers were used to collect daily and weekly composite samples because of the remoteness of the station and frequency of sampling. At Stations A, B, and D, structures such as a bridge or platform over the channel permitted the collection of mid-channel, depth-integrated samples. At other stations, a grab sample was collected from the stream bank. With respect to stream hydrology, lateral and vertical homogeneity was assumed for dissolved constituents at all sampling stations.

Modifications to the Water Quality Monitoring Program

During the Phase I of the GBP a number of issues were resolved with respect to the water quality monitoring program. These modifications and clarifications to the monitoring program are discussed in the first five Annual Reports (USBR, 1998 and SFEI, 1999, 2000, 2001, and 2002).

Water Quality Trends

Detailed water quality data for each monitoring station are presented in the Grassland Bypass Project Annual Narrative and Graphical Summary, October 2001 to December 2002 (SFEI, 2003). Thus, this presentation will be limited to major water quality trends and findings for the first 15-month period of operation of Phase II of the GBP. Of primary interest are selenium concentrations in the San Joaquin River and water quality trends in Mud Slough (north). Also of interest are sporadic exceedances in the wetland channels of selenium water quality objectives established in the Water Quality Control Plan for the Sacramento/San Joaquin River Basins.

San Joaquin River

The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) contains a schedule for compliance with the 5 µg/L (4-day average) selenium water quality objective and performance goals. The compliance date is either October 1, 2005 or October 1, 2010, depending on water year type (wet, dry, etc.) (Table 2). Compliance with selenium water quality objectives and performance goals specified in the Basin Plan is measured at Station N.

Figure 1 depicts selenium concentrations in the San Joaquin River at monitoring Stations G (weekly grab), and N (4-day average) from October 2001 through December 2002. Station G is located at Fremont Ford, upstream of the Mud Slough (north) inflow to the San Joaquin River. Because this station is located upstream of drainage discharges from the GBP service area (except during flood events when drainage has occasionally been routed to Salt Slough), selenium concentrations are relatively low, and remained below 2 µg/L throughout the 15-month period.

Station N is located downstream of the GBP discharges conveyed by Mud Slough (north) and the Merced River inflow to the San Joaquin River. Merced River inflows dilute the upstream selenium contributions (CVRWQCB, 2002). During the 15-month period, selenium concentrations were above 5 µg/L for short periods of time during the months of June and July. The maximum daily concentration observed in the San Joaquin River was 6.8 µg/L at Station N on July 2, 2002.

On October 1, 2002 a performance goal of either 5 µg/L or 8 µg/L monthly mean selenium concentration (depending on water year type) became effective in the San Joaquin River below the confluence with the Merced River. Figure 2 depicts monthly mean selenium concentrations at Station N for the 15-month period. As of October 1, 2002, the applicable performance goal for a dry year, such as WY 2002, is an 8 µg/L monthly mean selenium concentration. Monthly mean selenium concentrations during the 15-month period did not exceed 5 µg/L. Thus, it appears that the GAF have demonstrated the capability of meeting these performance goals

The Basin Plan and the GBP Waste Discharge Requirements (WDRs) prohibit discharge of selenium from agricultural subsurface drainage systems in the Grassland Watershed to the San Joaquin River in amounts exceeding 8,000-pounds per year. Calculations using daily selenium data, preliminary USGS flow data, and the load calculation methods found in CVRWQCB

(1998b) indicate that the annual selenium load measured at Station N during WY 2002 was well below the 8,000-pound annual load limit for the Grassland Watershed.

Wetland Channels

Monthly mean selenium concentrations in the wetland channels for the 15-month period are depicted in Figure 3. The monthly mean 2 µg/L selenium objective was met during all months in Salt Slough. The monthly mean 2 µg/L selenium objective was exceeded in February for Stations J, K, and L2, and in March and April for Station J. The maximum observed monthly mean concentrations of 2.9 µg/L at Stations J and K, and 2.4 µg/L at Station L2, however, are substantially lower than pre-Project concentrations (CVRWQCB, 1998c).

Regional Board staff conducted preliminary investigations on the potential sources of selenium, which are detailed in two separate reports (CVRWQCB, 2000 and CVRWQCB, 2002). In summary, primary sources of selenium to the channels were determined to be diversions from the 94,000-acre Drainage Project Area (DPA) (both stormwater flows and seepage from control gates), supply water, subsurface agricultural drainage from areas outside of the DPA, tailwater and local groundwater. To address the first source, diversions from the DPA, the Grassland Area Farmers (GAF) developed a stormwater management plan, and internal control gates were sealed. These actions appear to have controlled peaks of selenium previously observed during storm events.

Despite the stormwater management plan and control gate modifications made by the GAF, selenium concentrations have continued to sporadically exceed the 2 µg/l monthly mean selenium objective in the wetland channels, particularly from the pre-irrigation season through the early irrigation season (February through April). As a result of the continued elevated selenium concentrations, staff focused the ongoing investigations on potential selenium sources outside of the GBP area: supply water and subsurface agricultural drainage from outside of the GBP service area. Results are currently under review and will be used to direct the ongoing investigation.

Mud Slough (North)

Results of weekly grab sampling for selenium at Station D, Mud Slough (north) downstream of the SLD, are depicted in Figure 4. Selenium concentration distributions as a function of time were similar for all water years. Selenium concentrations tend to be lowest from the fall through early winter (non-irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer. During the 15-month period, selenium concentrations in Mud Slough (north) downstream of the SLD ranged from 3.2 µg/L in November 2001, to 54.9 µg/L in April 2002. Water quality in Mud Slough (north) downstream of the SLD is dominated by the GBP drainage discharge. For comparison purposes, the 5 µg/L (4-day average) selenium water quality objective, which applies October 1, 2010 for Mud Slough (north), is noted on Figure 4. Selenium concentrations regularly exceeded 5 µg/L in Mud Slough (north) downstream of the SLD inflow. Upstream of the drainage discharge, the concentration of selenium was usually below 2 µg/L, and the maximum observed selenium concentration of 1.2 µg/L was observed in both April and August 2002 (Figure 5).

Boron Water Quality Objectives

Boron water quality objectives and monthly mean boron concentrations for Mud Slough, Salt Slough, and the San Joaquin River during the 15-month period are presented in Table 3. Exceedances of the 2.0 mg/L objective occurred at Station C in March and April 2002, and at Station D from March through September 2002. The 1.0 mg/L objective was exceeded at Station N during February and March, and the 0.8 mg/L objective was exceeded at Station N during March and April and from June through September 15, 2002. Sources of boron occur throughout the San Joaquin Basin and are not restricted to the GBP (CVRWQCB, 2002). The CVRWQCB is concurrently conducting a separate effort to control salt and boron loading to the lower San Joaquin Basin.

Molybdenum Water Quality Objectives

Molybdenum water quality objectives and monthly mean molybdenum concentrations for Mud Slough, Salt Slough, and the San Joaquin River during the 15-month period are presented in Table 4. The data indicates that molybdenum concentrations were below the water quality objectives in Mud Slough, Salt Slough, and the San Joaquin River throughout the 15-month period.

Nutrient Data

CVRWQCB staff collected nutrient samples at Stations C, G, and N. Laboratory results for many of the nutrient samples did not meet the recovery criteria specified in the WDRs. Due to lab turnaround-time and holding-time issues, these samples could not be reanalyzed. As a result, these data were not reported. As discussed in Chapter 11, the University of California at Davis, under contract with the USFWS, collected and analyzed samples from Stations B and D. A data audit by the GBP Quality Assurance Officer revealed that external quality assurance data were not available for the water samples collected at Sites B and D. As the quality of these data could not be confirmed, these data were not reported and are not included in this report. The DCRT has taken measures to correct the collection and analysis problems with the nutrient data.

Available nutrient data for Mud Slough (north), and the San Joaquin River are presented in Tables 5, 6, and 7. For comparison purposes, the Primary Maximum Contaminant Level (MCL) for nitrate in drinking water (expressed as nitrogen) is 10 mg/L (CVRWQCB, 2003). Nitrate levels were below the MCL at Stations C, G, and N in all samples. Freshwater aquatic life criteria for ammonia are found in CVRWQCB (2003). Ammonia levels were below the toxicity threshold at Stations C, G, and N in all samples. Although there are currently no water quality objectives with which to evaluate the remaining constituents, they continue to be collected to aid in the development of a TMDL for oxygen demanding substances in the San Joaquin River and future nutrient criteria.

Conclusions

Monitoring has shown that selenium concentrations in the San Joaquin River are a function of location in the River with respect to discharge points and tributary inflows, and of the assimilative capacity of the River. The lowest selenium concentrations in the San Joaquin River are upstream of Mud Slough (north) inflows. Mud Slough (north) inflow contains relatively high

concentrations of selenium. The Merced River dilutes the San Joaquin River with respect to selenium. Selenium concentrations in the San Joaquin River at Station N, however, remain elevated relative to the background condition in the San Joaquin River at Station G.

The 2 µg/L monthly mean selenium water quality objective was exceeded in three of the wetland supply channels during the 15-month period. The maximum monthly mean observed was 2.9 µg/L at Station K (Agatha Canal) in February and 2.9 µg/L Station J in March. A number of sources may contribute to the exceedances of selenium water quality objectives in the wetland channels, including agricultural subsurface drainage from areas outside the GBP being discharged to the channels upstream of the wetlands. Regional Board staff is conducting ongoing investigations focusing on identifying sources of selenium that contribute to exceedances of the selenium water quality objective in the wetland supply channels. The results of these investigations are detailed in separate reports that are available from the Regional Board. The CVRWQCB is evaluating control actions to reduce selenium concentrations in the wetland channels.

The water quality of Mud Slough (north) downstream of the SLD inflow is governed by the GBP drainage discharge and fluctuates widely. Selenium concentrations tend to be lowest from the fall through early winter (non-irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer. Selenium concentrations regularly exceeded 5 µg/L in Mud Slough (north) downstream of the SLD inflow. Upstream of the drainage discharge, the concentration of selenium was usually below 2 µg/L.

Boron and molybdenum water quality data from Mud Slough (north), Salt Slough, and the San Joaquin River were compared to applicable water quality objectives. Boron water quality objectives were exceeded at Mud Slough and in the San Joaquin River (Table 3). The exceedances occurred during the irrigation season. Sources of boron occur throughout the San Joaquin Basin and are not restricted to the GBP. The CVRWQCB is concurrently conducting a separate effort to control salt and boron loading to the lower San Joaquin Basin. Molybdenum water quality objectives were met in Mud Slough (north), Salt Slough, and the San Joaquin River throughout the 15-month period (Table 4).

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Table 1. Summary of Water Quality Monitoring Plan

Location	Site	Description	Purpose	Analytical Parameter	Frequency	Sampling Methodology
San Luis Drain	A	inflow to SLD	water quality of inflow (Se and TSS)	Se, B, EC	weekly composite	auto-sampler
				EC, TSS	weekly	mid-channel, depth integrated
	B	discharge from SLD	water quality of discharge (Se and TSS) (for Se load calculation)	Se, B, EC	daily composite	auto-sampler
				pH, EC, Temp, Se, B, TSS[1], Mo[2], Nutrients[3]	weekly	mid-channel, depth integrated
Mud Slough (north)	C	upstream of SLD discharge	Mud Slough (north) base water quality prior to receiving drainage discharges	pH, EC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab
	D	downstream of discharge	Mud Slough (north) water quality as impacted by drainage discharge	pH, EC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	mid-channel, depth integrated
	I/I2	back water	water quality impact of Mud Slough (north) flooding in Kesterson Refuge	Se, B, EC	annually	N/A
Wetland Channels	F	Salt Slough	water quality of habitat and to track	Se, B, EC	weekly	grab
	J	Camp 13	verify no discharge of drainage provision	Se, B, EC	weekly	grab
	K	Agatha Canal	verify no discharge of drainage provision	Se, B, EC	weekly	grab
	L2	San Luis Canal	water quality of wetland water supply channel	Se, B, EC	weekly	grab
	M2	Santa Fe Canal	water quality of wetland water supply channel	Se, B, EC	weekly	grab
San Joaquin River	G	at Fremont Ford (upstream of drainage inflow)	track improvements in former drainage conveyance channel and characterize water quality of habitat	pH, EC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab
	H	at Hill's Ferry (downstream of drainage inflow)	intended to represent water quality of river most impacted by drainage discharge	Se, B, EC	discontinued; determined to be downstream of seasonal Merced River inflows	grab
	N	at Crows Landing (downstream of Merced River confluence)	characterize water quality of habitat	Se, B, EC	daily composite	auto-sampler
				pH, EC, Temp, Se, B, Mo[2], Nutrients[3]	weekly	grab

Notes:

1 TSS required daily during storm events

2 Molybdenum required monthly

3 Nutrients required monthly September through February and every other week March through August

Table 2. Summary of Selenium Water Quality Objectives and Compliance Time Schedule

Water Body/Water Year Type (1)	1 October, 1996	1 October, 2002	1 October, 2005	1 October, 2010
Salt Slough and Wetland Water Supply Channels listed in Appendix 40 (4)	**2 µg/L monthly mean (2)**			
San Joaquin River below the Merced River; Above Normal, and Wet Water Year Types		*5 µg/L monthly mean (3)*	**5 µg/L 4-day average (2)**	
San Joaquin River below the Merced River; Critical, Dry, and Below Normal Water Year Types		*8 µg/L monthly mean (3)*	*5 µg/L monthly mean (3)*	**5 µg/L 4-day average (2)**
Mud Slough (north) and the San Joaquin River from Sack Dam to the Merced River				**5 µg/L 4-day average (2)**

(1) The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley water year hydrologic classification (as defined in Footnote 17 for Table 3 in the State Water Resources Control Board's Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, May 1995) at the 75% exceedance level using data from the Department of Water Resources Bulletin 120 series. The previous water year's classification will apply until an estimate is made of the current water year.

(2) Water Quality Objective (in bold)

(3) Performance Goal (in italics)

(4) CVRWQCB. 1998a. Appendix 40, The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Fourth Edition: The Sacramento River Basin and the San Joaquin River Basin. California Regional Water Quality Control Board, Central Valley Region. Sacramento, CA

Table 3. Boron Concentrations in the Grassland Watershed and San Joaquin River: October 2001 - December 2002

Station ID	Description	Mean Monthly Concentration (mg/L) Oct-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02		Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02		Oct-02	Nov-02
C	Mud Slu (N) upstrm of SLD Discharge	a	a	a	a	a	na	2.8	2.3	1.9	1.6	1.5	1.1	0.8	na	a	a
D	Mud Slu (N) dwnstrm of SLD Discharge	a	a	a	a	a	na	3.8	5.9	5.5	6.1	5.9	5.1	4.6	na	a	a
F	Salt Slough at Lander Avenue	a	a	a	a	a	1.5	na	0.7	0.6	0.5	0.6	0.5	0.5	na	a	a
G	SJR at Fremont Ford	a	a	a	a	a	1.1	na	0.8	0.7	0.6	0.6	0.5	0.6	na	a	a
N	JR at Crows Landing Weekly Grab Sampl	0.5	0.5	0.7	0.8	1.1	1.4	1.3	1.0	0.8	1.2	1.2	1.2	1.0	0.9	0.6	0.8
N	SJR at Crows Landing Daily Autosamples	0.7	na	na	na	1.2	1.3	1.4	1.0	0.7	1.2	1.3	1.2	1.1	0.9	0.6	0.7

Notes:

[shaded box] = water quality objective exceedance

WQO = water quality objective in mg/L

na = no data available

a = objective only applies 15 March through 15 September

[1] = 1.0 mg/L applies 16 September through 14 March

0.8 mg/L applies 15 March through 15 September

Table 4. Molybdenum Concentrations in the Grassland Watershed and San Joaquin River: October 2001 - December 2002

Station ID	Description	Mean Monthly Concentration (ug/L) Oct-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Monthly WQO
C	Mud Slu (N) upstrm of SLD Discharge	5.5	5.6	7.6	6.8	6.9	17.1	10.4	16.9	10.3	0.5	4.6	3.2	na	4.3	4.9	19.0
D	Mud Slu (N) dwnstrm of SLD Discharge	9.9	10.1	11.3	11.5	12.1	12.9	16.8	19.1	19.3	9.7	11.3	11.4	na	7.2	6.7	19.0
F	Salt Slough at Lander Avenue	8.5	7.9	11.0	8.3	8.0	11.2	10.8	8.0	8.0	0.5	1.8	4.4	na	5.0	3.8	19.0
G	SJR at Fremont Ford	na	na	na	na	na	na	na	11.4	8.0	2.2	na	na	na	5.1	1.0	19.0
N	SJR at Crows Landing Grab Samples	2.7	3.9	5.2	6.0	7.3	8.4	5.4	6.9	6.4	1.8	0.5	3.6	na	3.7	3.8	10.0

Notes:

[shaded box] = water quality objective exceedance

WQO = water quality objective in ug/L

na = no data available

Table 5. Nutrient Series Data, Site C, Mud Slough (North) Upstream of SLD (MER536)

Parameter	Nitrate	Dissolved Nitrate-Nitrite	Dissolved Ammonia	Total Kjeldhal Nitrogen	Total Phosphorus	Ortho Phosphate
Units	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L	mg/L as P
10/1/2001						
11/1/2001		0.27				0.20
12/1/2001		0.17		0.80	0.17	0.12
1/1/2002					0.19	
2/1/2002						0.27
3/14/2002						
3/28/2002						
4/11/2002						
4/25/2002		0.67			0.34	
5/16/2002						
5/30/2002						0.22
6/13/2002						
6/20/2002		0.59		1.02	0.29	0.12
7/18/2002	ND*		<1	<2		<1
7/25/2002	0.9		<1	<2	0.19	<1
8/15/2002	ND*		<1	<2	0.25	<1
8/29/2002		0.03		1.37	0.30	0.07
9/1/2002		0.03		0.79		0.09
10/1/2002		0.08		1.24	0.34	0.30
11/1/2002		0.19		1.23	0.33	0.24
12/1/2002		0.24		1.28	0.28	0.02

Data Source: California Regional Water Quality Control Board, Central Valley Region

Note: * <2 mg/L NO_3 as NO_3

Table 6. Nutrient Series Data, Site G, San Joaquin River at Fremont Ford (MER538)

Parameter	Nitrate	Dissolved Nitrate-Nitrite	Dissolved Ammonia	Total Kjeldhal Nitrogen	Total Phosphorus	Ortho Phosphate
Units	mg/L as N	mg/L as N	mg/L as N	mg/L	mg/L	mg/L as P
10/1/2001						
11/1/2001		0.34				0.07
12/1/2001		0.38			0.14	0.02
1/1/2002					0.16	
2/1/2002		2.28			0.23	0.08
3/14/2002		2.33				0.11
3/28/2002		1.16		1.08	0.21	0.06
4/11/2002		0.94		0.69	0.19	0.04
4/25/2002		0.73			0.27	
5/16/2002		0.64				0.13
5/30/2002		0.60				0.16
6/13/2002	2.7				0.29	0.14
6/20/2002		1.69		1.16		0.14
7/18/2002	1.4		<1	<2		0.17
7/25/2002	1.4		<1	<2	0.33	0.16
8/15/2002	0.9		<1	<2	0.26	0.16
8/29/2002		0.39		1.00		0.15
9/1/2002		0.16		0.60	0.18	0.12
10/1/2002		0.32		0.75	0.21	0.10
11/1/2002		0.26		1.10	0.12	0.04
12/1/2002		0.56		1.76	0.20	0.09

Data Source: California Regional Water Quality Control Board, Central Valley Region

Table 7. Nutrient Series Data, Site N, San Joaquin River at Crows Landing (STC504)

Parameter Units	Nitrate mg/L as N	Dissolved Nitrate-Nitrite mg/L as N	Dissolved Ammonia mg/L as N	Total Kjeldhal Nitrogen mg/L	Total Phosphorus mg/L	Ortho Phosphate mg/L as P
10/1/2001						
11/1/2001		1.33				0.10
12/1/2001		1.32		0.36	0.13	0.05
1/1/2002					0.15	
2/1/2002						0.09
3/14/2002		3.26				0.11
3/28/2002		2.41		1.12	0.18	0.10
4/11/2002		2.43		0.63	0.16	0.05
4/25/2002		2.66			0.17	
5/16/2002		1.54				0.12
5/30/2002						0.12
6/13/2002	3.8				0.16	<1
6/20/2002		4.35		1.15	0.22	0.06
7/18/2002	5.2		<1	<2		0.11
7/25/2002	2.5		<1	<2	0.29	<1
8/15/2002	2.5		<1	<2	0.15	<1
8/29/2002		3.65		1.14	0.25	0.10
9/1/2002		3.81		0.61		0.14
10/1/2002						
11/1/2002		1.4		1.12	0.11	0.10
12/1/2002		1.35		1.31	0.20	0.02

Data Source: California Regional Water Quality Control Board, Central Valley Region

Figure 1. Selenium Concentration in the San Joaquin River October 2001 - December 2002

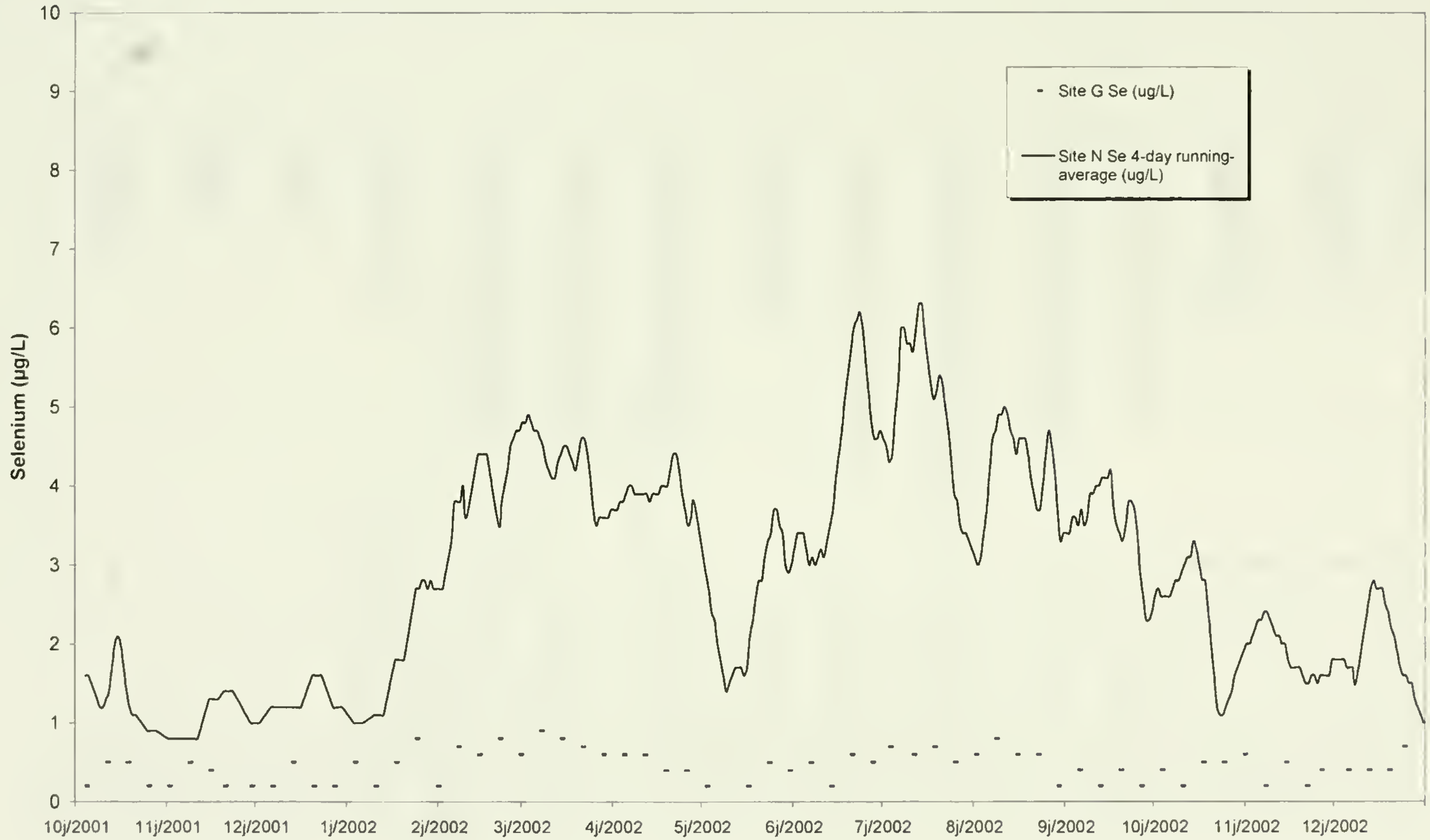


Figure 2. Monthly Mean Selenium Concentration at Site N
October 2001 - December 2002

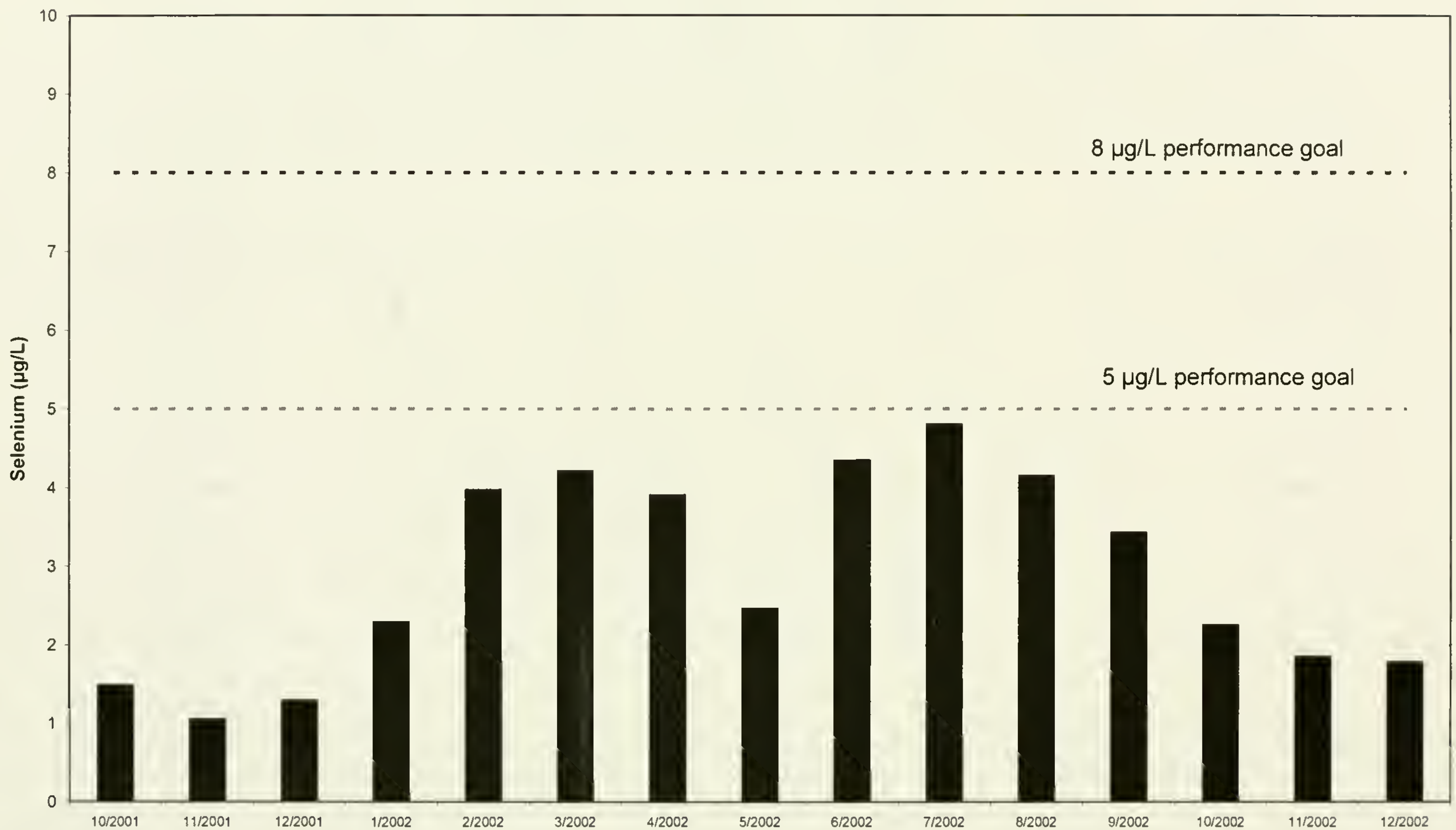


Figure 3. Mean Monthly Selenium Concentration in the Grassland Wetland Supply Channels October 2001 -December 2002

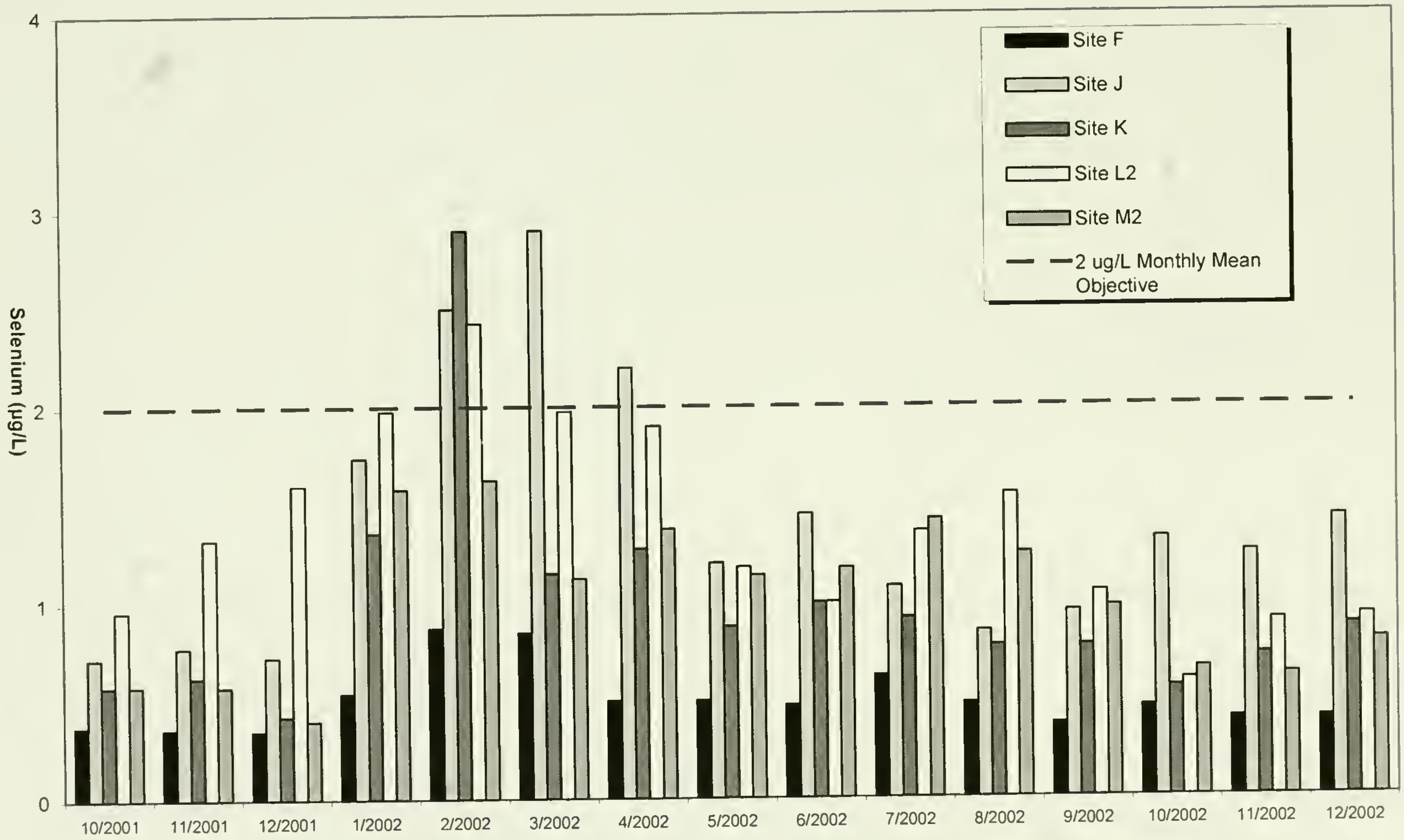


**Figure 4. Weekly Grab Selenium Concentration at Site D
October 2001 - December 2002**

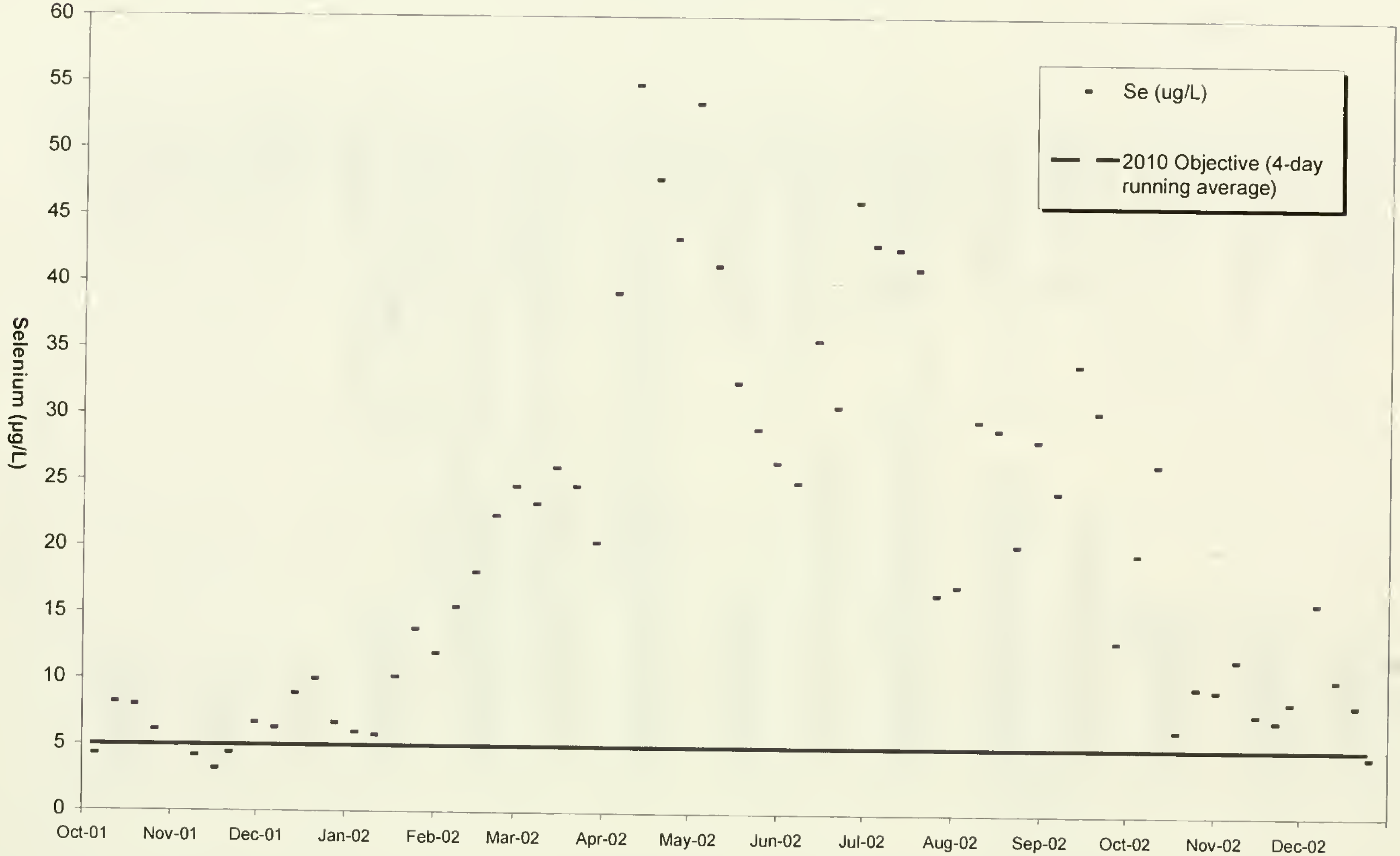
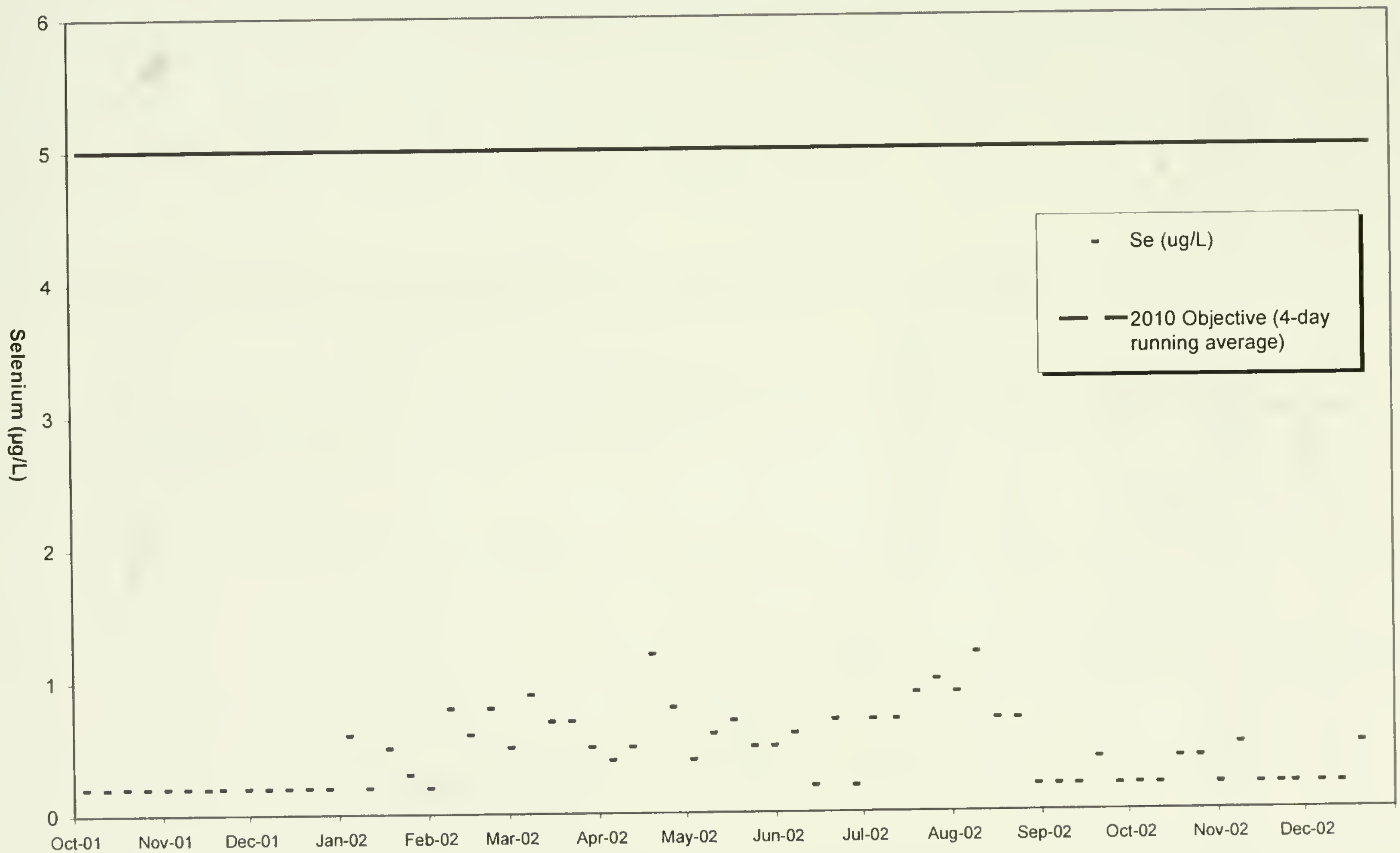


Figure 5. Weekly Grab Selenium Concentration at Site C
October 2001 - December 2002



5

Flow, Salt and Selenium Mass Balances in the San Luis Drain

October 1, 2001 – December 31, 2002

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Grassland Bypass Project

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Summary

Although lined with concrete along the 28 mile reach utilized by the Grassland Bypass Project (GBP), about 4,000 acre-feet of water entered the San Luis Drain (SLD) between Stations A and B during the fifteen month study period of October 2001 – December 2002. This was a fourteen percent increase in the SLD (Table 1a). The increases in flow occurred during October, November, and December 2001, and during August through December 2002. The reason for differences in flow may be due to water seeping into the SLD when adjacent wetlands are flooded.

There was a net increase in salt load of about 9,000 tons (seven percent) during the fifteen month study period (Table 2a).

There was a three percent increase of about 149 pounds of selenium between the monitoring sites during the fifteen month study period (Table 3a). The difference in selenium between the sites may be due to measurement error, microbial uptake, adsorption to sediments, volatilization, or seepage of seleniferous water into the drain between Stations A and B.

Tables 1b, 2b, and 3b summarize monthly flows, salt loads, and selenium loads that passed Stations A and B during the six water years of the Project. Tables 1c, 2c, and 3c summarize monthly flows, salt loads, and selenium loads that passed Stations A and B during the six calendar years of the Project. Table 4 summarizes the effects of rainfall and evapotranspiration on the volume of water in the SLD.

Note that the historical concentration and load values have been updated and differ from those in the 1999 Annual Report and errata sheets.

Background

Seepage into the SLD most likely occurs through cracks and one-way weep valves that equalize hydraulic pressure to prevent the concrete lining from buckling. Along the SLD, the water surface elevation of adjacent wetlands, when flooded in the fall and winter, is often higher than the elevation of water in the SLD.

Leakage from the SLD can occur where the concrete lining is fractured or between adjacent concrete panels. Other losses from the SLD include direct evaporation of water and evapotranspiration by algae and aquatic plants.

Flow Differences between Stations A and B

Tables 1a, 1b, and 1c summarize the amount of water that flowed past Stations A and B during the six years of the Project. Figure 1 compares the monthly flows of water that passed Stations A and B during the fifteen month reporting period.

About 4,000 acre-feet more water flowed past Station B than Station A during the fifteen month study period, representing a 14 percent increase in flow (Table 1a). There was increase flow during October 2001 through March 2002 and again during August 2002 through December 2002 while adjacent wetlands were flooded. The increase in flow during the 2002 Water Year was eleven percent, compared to increase of four to six percent in previous Water Years (Table 1b). The increase in flow during the 2002 Calendar Year was nine percent, compared to increase of four to seven percent in previous Calendar Years (Table 1c).

Table 4 calculates the net water gain or loss in acre-feet per month by taking into account precipitation and evaporation from the surface area of the Drain. Once precipitation and evaporation are accounted for, the difference in flow between Stations A and B ranges from zero percent to six percent for February through July 2002 (Column 17). These differences are within the margin of error for flow measurements specified in the Quality Assurance Project Plan (Reclamation, et. al. 2002). The remaining months (October 2001 – January 2002, August – September 2002) show large increases in flow (16 - 43 percent), most likely seepage into the drain from adjacent wetland ponds.

Salt Mass Balance between Stations A and B

Tables 2a, 2b, and 2c compare monthly and annual loads of salt in water that passed Stations A and B during the six years of the Project. There was a seven percent increase of about 9,000 tons of salt between Stations A and B during the fifteen month study period (Table 2a). There was a four percent increase of salts during the 2002 Water Year of about 4,400 tons (Table 2b).

Figure 2 shows the monthly loads of salt in water that passed Stations A and B during WY 2002.

Since salinity is a conservative chemical constituent, the monthly salt load measured at Station A should be identical to that at Station B. An increase in salt load must infer inflow of saline water into the SLD from adjacent wetlands if other factors such as precipitation and evaporation are taken into account. A decrease in salt load would infer the loss of saline water from the drain.

The WY 2002 monthly differences in salt loads, ± 15 percent, are probably the result of cumulative errors from different analytical methods and equipment. Flow at Station A is measured as flow over a sharp-crested weir with a precision of ± 5 percent. The USGS developed a stage-discharge rating curve for Station B; the accuracy of flow measurements with this method is between – 4 % and + 6 percent.
Drift in the EC sensor response can also affect the computation of salt load. However, EC is measured with identical sensors and methods at both sites. USGS staff consider the EC sensor at Station B to be accurate within three percent. In previous years, algae bio-fouling of the probe at Station B has caused errors of more than 30 percent during summer months, but diligent maintenance prevented this from occurring and kept the rate of error less than ten percent. The difference in flow-weighted average EC between the stations was about eight percent (4,492 vs. 4,116 μS/cm), as shown in Table 2a.

Selenium Mass Balance between Stations A and B

A simple mass balance of selenium was calculated to better understand the dynamics of selenium mass transport and mass transfer within the San Luis Drain. Selenium is a non-conservative chemical constituent. The data are presented in Tables 3a, 3b, and 3c. Despite the seepage inflow, there was a three percent difference in the loads of selenium that passed each station during the fifteen month study period (Table 3a). About 153 pounds of selenium entered the drain between Station A and Station B during the 2002 Water Year (Table 3b). More

selenium passed Station B than Station A during every month except January 2002, April 202, and December 2002.

The largest increases occurred during December 2001, May 2002, and August 2002 (Table 3a). The pattern of increases in selenium does not coincide with the increases in flows while adjacent wetlands are flooded.

The monthly differences in selenium loads are within the range of error caused by the different methods of measuring flow and collecting water samples at each station. Flow data, when combined with continuous and discrete selenium data, are used to compute this mass balance. As mentioned before, flow is measured differently at each site, and selenium sampling does not occur at the same frequency at both Stations A and B.

During WY 2002, selenium samples were collected by auto-samplers at both sites. At Station B, seven samples were collected each day; the composite of each day's samples were analyzed in the laboratory. At Station A, seven daily samples were mixed to produce a single weekly composite for analysis.

Figure 3 shows the monthly loads of selenium at both sites during the WY 2002.

Conclusions

In the six years of the GBP, there have been increases in the flow of water in the San Luis Drain during autumn, winter, and late summer months when adjacent wetlands are flooded. The eleven percent net increase in flow between Stations A and B was the highest during the Water Year 2002, compared to previous water years' increases of four to six percent (Table 1b).

The loads of salt have varied each water year from a net loss of six percent to a gain of four percent (Table 2b). These differences are within the realm of measurement error.

The water year loads of selenium have varied from a net loss of seven percent to a gain of six percent (Table 3b). These differences are within the realm of measurement and sampling error. The differences in selenium loads due to natural processes cannot be determined.

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Table 1a. Comparison of Flow Measurements (October 2001 - December 2002)

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A af/month	Station B af/month	Difference	Percent of Station B
Oct-2001	11	18	672	1,100	428	39%
Nov-2001	13	22	749	1,320	571	43%
Dec-2001	12	20	755	1,250	495	40%
Jan-2002	22	27	1,323	1,660	337	20%
Feb-2002	47	49	2,593	2,730	137	5%
Mar-2002	52	55	3,182	3,370	188	6%
Apr-2002	42	41	2,484	2,430	-54	-2%
May-2002	42	43	2,588	2,640	52	2%
Jun-2002	55	56	3,269	3,320	51	2%
Jul-2002	53	53	3,230	3,260	30	1%
Aug-2002	54	55	3,318	3,410	92	3%
Sep-2002	28	32	1,658	1,910	252	13%
Oct-2002	15	20	901	1,240	339	27%
Nov-2002	15	19	865	1,150	285	25%
Dec-2002	18	22	1,112	1,360	248	18%
Fifteen month average	32	35	1,913	2,143		
Fifteen month total			28,700	32,150	3,450	12%

Data sources: Station A - San Luis & Delta-Mendota Water Authority
Station B - US Geological Survey Site 11262895

Table 1b. Comparison of Flow Measurements, Water Years 1997 – 2002

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A af/month	Station B af/month	Difference	Percent of Station B
WY 1997	52	52	37,786	37,549	-237	-1%
WY 1998	61	64	43,550	45,940	2,390	5%
WY 1999	42	45	30,470	32,310	1,840	6%
WY 2000	40	43	29,350	31,260	1,910	6%
WY 2001	37	39	27,005	28,254	1,249	4%
WY 2002	36	39	25,822	28,400	2,578	9%

Data source: Grassland Bypass Project Annual Report 2000 - 2001

Table 1c. Comparison of Flow Measurements, Calendar Years 1997 - 2002

	Monthly Average Flow		Total Flow			
	Station A cfs	Station B cfs	Station A af/month	Station B af/month	Difference	Percent of Station B
CY 1997	51	52	36,580	37,478	898	2%
CY 1998	62	64	44,201	46,240	2,039	4%
CY 1999	41	45	29,869	32,250	2,381	7%
CY2000	40	42	28,939	30,210	1,271	4%
CY 2001	36	39	26,143	28,014	1,871	7%
CY 2002	37	39	26,524	28,480	1,956	7%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 2a. Comparison of Salinity and Salt Loads (October 2001 - December 2002)

	Flow-weighted Electrical Conductivity		Salt Loads			
	Station A µS/cm	Station B µS/cm	Station A tons/month	Station B tons/month	difference	Percent of Station B
Oct-2001	4,980	3,879	3,368	4,294	926	22%
Nov-2001	4,460	3,782	3,362	5,024	1,662	33%
Dec-2001	4,760	4,219	3,618	5,308	1,690	32%
Jan-2002	4,820	4,287	6,419	7,162	743	10%
Feb-2002	4,390	4,314	11,457	11,853	396	3%
Mar-2002	4,630	4,391	14,826	14,892	66	0%
Apr-2002	4,700	4,650	11,750	11,372	-379	-3%
May-2002	4,430	4,171	11,538	11,082	-456	-4%
Jun-2002	4,170	3,931	13,719	13,134	-585	-4%
Jul-2002	3,910	3,886	12,710	12,749	39	0%
Aug-2002	3,580	3,474	11,954	11,922	-32	0%
Sep-2002	4,350	3,843	7,258	7,387	129	2%
Oct-2002	5,040	4,177	4,570	5,213	643	12%
Nov-2002	4,870	4,182	4,240	4,840	601	12%
Dec-2002	4,900	4,556	5,484	6,236	752	12%
Fifteen month ave	4,533	4,116				
Fifteen month total			126,275	132,468	6,194	5%

Data sources: Station A - San Luis & Delta-Mendota Water Authority
Station B - US Geological Survey Site 11262895

Table 2b. Comparison of Salinity and Salt Loads, Water Years 1997 – 2002

	Flow-weighted Electrical		Salt Loads			
	Station A µS/cm	Station B µS/cm	Station A tons/month	Station B tons/month	difference	Percent of Station B
WY 1997	4,477	4,257	176,433	167,739	-8,694	-5%
WY 1998	4,625	4,439	195,263	205,104	9,841	5%
WY 1999	4,821	4,650	143,705	149,133	5,427	4%
WY 2000	4,478	4,301	129,368	134,994	5,626	4%
WY 2001	4,634	4,202	125,394	120,008	-5,386	-4%
WY 2002	4,432	4,069	111,981	116,180	4,198	4%

Data source. Grassland Bypass Project Annual Report 2000 - 2001.

Table 2c. Comparison of Salinity and Salt Loads, Calendar Years 1997 – 2002

	Flow-weighted Electrical		Salt Loads			
	Station A µS/cm	Station B µS/cm	Station A tons/month	Station B tons/month	difference	Percent of Station B
CY 1997	4,627	4,354	173,154	169,236	-3,918	-2%
CY 1998	4,699	4,563	199,506	208,884	9,378	4%
CY 1999	4,767	4,532	139,922	146,530	6,607	5%
CY 2000	4,379	4,189	126,124	128,576	2,453	2%
CY 2001	4,668	4,200	121,678	119,266	-2,412	-2%
CY 2002	4,483	4,155	115,926	117,842	1,916	2%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 3a. Comparison of Selenium Measurements (October 2001 - December 2002)

	Flow-weighted Selenium Concentration		Total Selenium Loads			
	Station A µg/L	Station B µg/L	Station A lbs/month	Station B lbs/month	Difference	Percent of Station B
Oct-2001	61.8	39.9	113	118	7	6%
Nov-2001	71.5	42.1	146	148	6	4%
Dec-2001	57.4	49.3	118	170	50	30%
Jan-2002	73.6	54.6	265	246	(19)	-8%
Feb-2002	66.3	65.1	468	483	15	3%
Mar-2002	66.4	63.8	575	586	9	2%
Apr-2002	75.3	75.7	509	500	(9)	-2%
May-2002	46.2	50.6	325	363	38	11%
Jun-2002	43.9	44.0	390	397	7	2%
Jul-2002	39.1	41.1	343	365	21	6%
Aug-2002	34.2	34.7	308	322	64	20%
Sep-2002	50.4	46.4	227	241	14	6%
Oct-2002	89.7	63.9	220	216	(8)	-4%
Nov-2002	89.8	69.4	211	216	5	2%
Dec-2002	80.2	65.4	242	241	(1)	0%
Fifteen month ave	63.1	53.7				
Fifteen month totals			4,460	4,612	152	3%

Data Sources: Station A - Calculated from weekly composite samples collected by the Regional Board (Site MER562s)
Station B - Calculated from daily composite samples collected by the Regional Board (Site MER535s)

Table 3b. Comparison of Selenium Measurements, Water Years 1997 - 2002

	Average Flow-weighted		Total Selenium Loads			
	Station A µg/L	Station B µg/L	Station A pounds	Station B pounds	Difference	Percent of Station B
WY 1997	67.6	62.8	7,431	6,960	(471)	-7%
WY 1998	69.1	66.4	8,244	8,763	519	6%
WY 1999	66.5	58.9	5,257	5,124	(133)	-3%
WY 2000	65.7	54.0	4,669	4,603	(65)	-1%
WY 2001	62.6	56.0	4,493	4,377	(116)	-3%
WY 2002	57.2	50.6	3,737	3,940	203	5%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 3c. Comparison of Selenium Measurements Calendar Years 1997 - 2002

	Average Flow-weighted Concentration		Total Selenium Loads			
	Station A µg/L	Station B µg/L	Station A pounds	Station B pounds	Difference	Percent of Station B
CY 1997	67.1	60.8	7,170	6,854	(316)	-5%
CY 1998	70.5	67.8	8,415	8,872	457	5%
CY 1999	65.2	56.8	5,089	4,992	(97)	-2%
CY 2000	66.1	54.6	4,615	4,507	(108)	-2%
CY 2001	61.6	54.8	4,316	4,302	(14)	0%
CY 2002	62.9	56.2	4,033	4,170	137	3%

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

4a. Grassland Bypass Project San Luis Drain Discharge Balance (October 2001 - December 2002)

	CIMIS Precipitation						CIMIS Evapotranspiration								
	Panoche inches (1)	Telles inches (2)	Los Banos inches (3)	Average inches (4)	Average feet (5)	Water Gain from Precip acre feet (6)	Panoche inches (7)	Telles inches (8)	Los Banos inches (9)	Average inches (10)	Average feet (11)	Water lost to Evap. acre feet (12)	Gain or Loss from Water Surface acre feet (13)	Station A acre feet	Station B acre feet
Oct-2001	0.37	-	0.51	0.29	0.02	2.5	4.28	4.16	3.94	4.13	0.34	(35.0)	(32.5)	672	1,100
Nov-2001	0.90	1.73	1.57	1.40	0.12	11.9	1.75	1.73	1.60	1.69	0.14	(14.4)	(2.5)	749	1,320
Dec-2001	1.49	1.32	2.05	1.62	0.14	13.7	0.98	0.83	0.82	0.88	0.07	(7.4)	6.3	755	1,250
Jan-2002	0.65	0.20	1.05	0.63	0.05	5.4	1.21	1.13	1.09	1.14	0.10	(9.7)	(4.3)	1,323	1,660
Feb-2002	0.13	0.16	0.34	0.21	0.02	1.8	2.36	2.37	2.07	2.27	0.19	(19.2)	(17.4)	2,593	2,730
Mar-2002	0.62	0.94	1.13	0.90	0.07	7.6	4.21	3.99	3.86	4.02	0.34	(34.1)	(26.5)	3,182	3,370
Apr-2002	0.24	0.39	0.19	0.27	0.02	2.3	5.83	5.50	5.12	5.48	0.46	(46.5)	(44.2)	2,484	2,430
May-2002	0.05	0.32	0.34	0.24	0.02	2.0	8.36	8.01	7.56	7.98	0.66	(67.7)	(65.7)	2,588	2,640
Jun-2002	-	0.64	-	0.21	0.02	1.8	9.32	8.97	8.62	8.97	0.75	(76.1)	(74.3)	3,269	3,320
Jul-2002	-	0.04	-	0.01	0.00	0.1	8.43	8.78	8.82	8.68	0.72	(73.6)	(73.5)	3,230	3,260
Aug-2002	-	-	-	-	-	-	7.11	7.46	7.46	7.34	0.61	(62.3)	(62.3)	3,318	3,410
Sep-2002	-	-	-	-	-	-	5.78	5.87	5.58	5.74	0.48	(48.7)	(48.7)	1,658	1,910
Oct-2002	-	-	-	-	-	-	4.13	4.10	3.83	4.02	0.34	(34.1)	(34.1)	901	1,240
Nov-2002	0.54	1.02	1.21	0.92	0.08	7.8	1.86	1.90	1.76	1.84	0.15	(15.6)	(7.8)	865	1,150
Dec-2002	2.07	2.46	3.27	2.60	0.22	22.1	1.08	1.08	1.05	1.07	0.09	(9.1)	13.0	1,112	1,360

Data sources: Precipitation and evapotranspiration: California Irrigation Management Information System
Station A flow: San Luis & Delta-Mendota Water Authority
Station B flow: US Geological Survey Site 11262895

Table 4b. Grassland Bypass Project San Luis Drain Discharge Balance, Water Years 2000 – 2002

	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water Gain from Precip acre feet	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water lost to Evap. acre feet	Gain or Loss from Water Surface acre feet	Site A acre feet	Site B acre feet
WY2000	4.38	4.65	7.84	5.62	0.47	47.7	58.04	58.87	56.44	57.78	4.82	(490)	(442)	29,350	31,260
WY2001	6.71	7.61	7.72	7.35	0.61	62.3	61.32	59.87	57.81	59.67	4.97	(506)	(444)	27,005	28,254
WY2002	4.45	5.74	7.18	5.79	0.48	49.1	59.62	58.80	56.54	58.32	4.86	(495)	(446)	25,822	28,400

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Table 4c. Grassland Bypass Project San Luis Drain Discharge Balance, Calendar Years 2000 – 2002

	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water Gain from Precip acre feet	Panoche inches	Telles inches	Los Banos inches	Average inches	Average feet	Water lost to Evap. acre feet	Gain or Loss from Water Surface acre feet	Site A acre feet	Site B acre feet
CY2000	6.52	5.88	8.67	7.02	0.59	59.6	56.55	57.14	55.41	56.37	4.70	(478)	(419)	28,939	30,210
CY2001	2.76	3.05	4.13	3.31	0.28	28.1	7.01	6.72	6.36	6.70	0.56	(57)	(29)	26,143	28,021
CY2002	4.30	6.17	7.53	6.00	0.50	50.9	59.68	59.16	56.82	58.55	4.88	(497)	(446)	26,524	28,480

Data source: Grassland Bypass Project Annual Report 2000 - 2001.

Notes: Table prepared by Summers Engineering, updated by US Bureau of Reclamation

(1) - (3) Precipitation in inches for CIMIS Stations 007, 056, and 124.
(4) Average of (1) through (3)
(5) (4) / 12 conversion from inches to feet
(6) (5) x SLD surface area. SLD surface area = 28 mi x 30' top width = 101.8 ac
(7) - (9) Evapotranspiration in inches for CIMIS Stations 007, 056, and 124.
(10) Average of (7) through (9)
(11) (7) / 12 conversion from inches to feet
(12) (9) x SLD surface area. SLD surface area = 28 mi x 30' top width
(13) (6) + (12)
(14) From Table 1
(15) Net water volume gained from or lost to local high ground water =
(16) Average daily flow (cfs) of the Net Water Gain
(17) (15) / Station B flow (from Table 1) x 100%

Figure 1. Comparison of Flows in the San Luis Drain October 2001 - December 2002

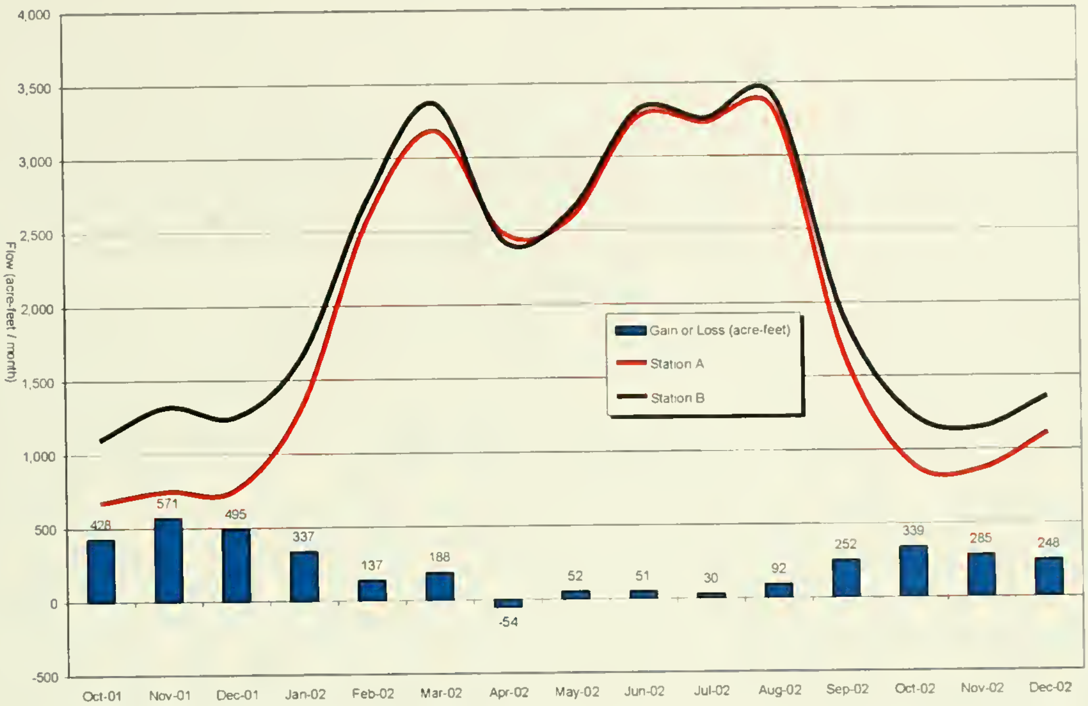


Figure 2. Comparison of Salt Loads in the San Luis Drain October 2001 - December 2002

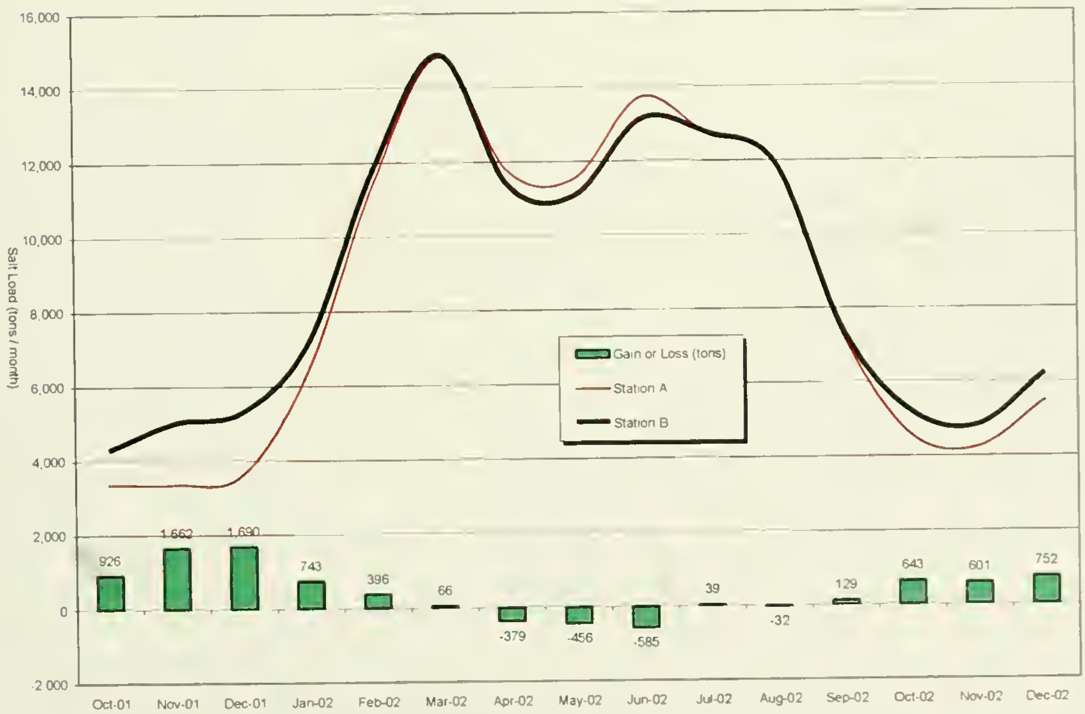
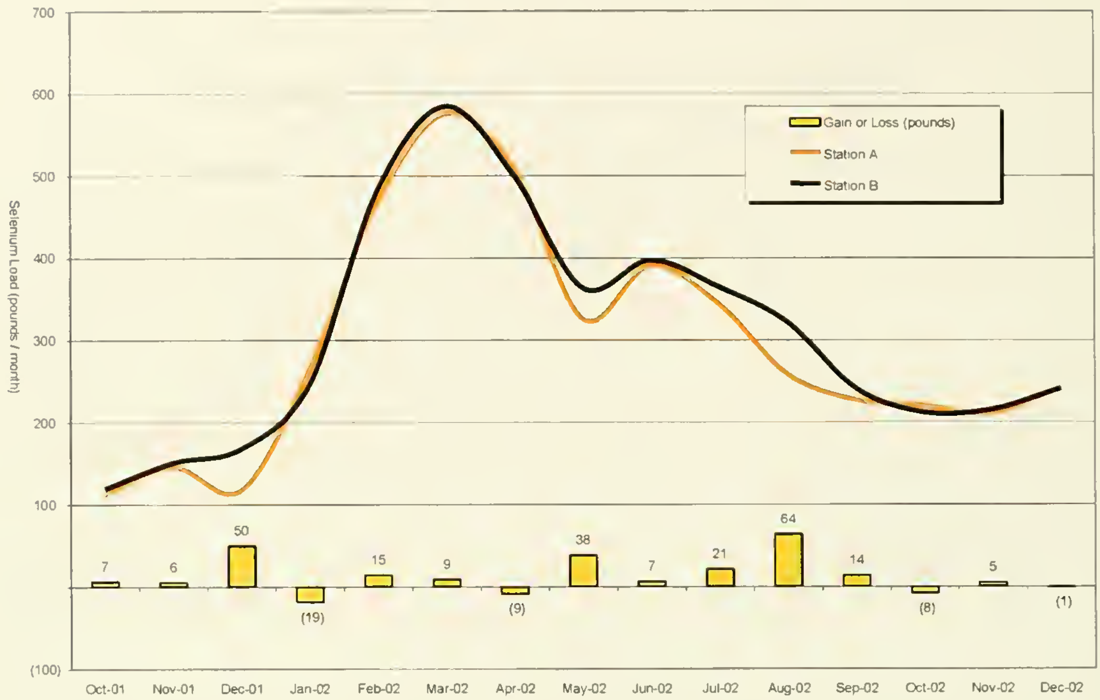


Figure 3. Comparison of Selenium Loads in the San Luis Drain October 2001 - December 2002



6 Project Impacts on the San Joaquin River

October 1, 2001 – December 31, 2002

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Introduction

The purpose of this chapter is to compare the loads of salt discharged by the Grassland Bypass Project (GBP) with loads that might exist in the absence of the project. This comparison uses flow and salinity data for Stations B, D, F, and N from October 1985 to December 2002. Two methods are used:

- Simple comparison of flow and salt loads as percentages, and
- A theoretical dilution analysis.

The theoretical dilution analysis was agreed upon in meetings involving the US Bureau of Reclamation (Reclamation), the South Delta Water Agency and its legal counsel, and the California Regional Water Quality Control Board, as a means of demonstrating that the Project was not causing adverse downstream impacts. This analysis was not specified in the Compliance Monitoring Program (Reclamation et. al., June 2002) or the Quality Assurance Project Plan (Reclamation et. al., August 2002). Work continues to standardize the methodologies used to calculate loads and the theoretical dilution.

The 2001 Agreement for Use of the San Luis Drain includes the following statement:

"*It is the objective and intention of RECLAMATION and the AUTHORITY, among other things, to ensure that continued use of the Drain as provided in this Agreement results in improvement in water quality and environmental conditions in the San Joaquin River, delta, and estuary relative to the quality that existed prior to the term of this Agreement, insofar as such quality or conditions may be affected by drainage discharges from the Drainage Area (as hereinafter defined), and to ensure that such continued use of the Drain does not reduce the ability to meet the salinity standard at Vernalis compared to the ability to meet the salinity standard that existed prior to the term of this Agreement.*" (Reclamation and San Luis & Delta-Mendota Water Authority, 2001)

Comparison of Flow and Salt Loads as Percentages

Tables 1a, 1b, and 1c compare the monthly flows and loads of salt discharged by the GBP with those in the San Joaquin River at Crows Landing through the six years of the Project. During the fifteen month study period (October 1, 2001 – December 31, 2002), the GBP contributed between two and fourteen percent of the flow, and 10 to 41 percent of the salt load, in the river each month (Table 1a). During WY 2002, overall discharge from the GBP was five percent of the flow and about 32 percent of the salt load in the river as measured at Crows Landing (Table 1b).

Tables 2a, 2b, and 2c compare the volumes of water discharged from the 97,000 acre Grassland Drainage Area (GDA) with flows in the Mud and Salt Slough watershed. The monthly discharge from the Grassland Drainage Area ranged from 12 to 32 percent of the regional flow during the fifteen month study period. (Table 2a). During the WY 2002, 28,400 acre-feet of water were discharged from the GDA, which was approximately 15 percent of the 185,140 acre-feet that flowed from the region (Table 2a). The WY 2002 volume was about 43 percent less than the average annual volume of drainage water discharged prior to the GBP (Table 2b).

Tables 3a, 3b, and 3c compare the loads of salts discharged from the GDA with the salts in water in Mud and Salt Sloughs. During the WY 2002, about 116,260 tons of salt were discharged from the GDA, which was almost 36 percent of the 319,660 tons that left the region through Mud and Salt Sloughs (Table 3a). The WY 2002 salt load was about 39 percent less than the average annual salt load discharged prior to the GBP (Table 3b). The WY 2002 regional salt load was about 18 percent less than the average annual salt load discharged prior to the GBP (Table 3b).

Theoretical Dilution of GBP Discharges to Meet Vernalis Standards

In order to assess the effect of GBP on salinity in the San Joaquin River, an analysis was developed to theoretically isolate the effects of GBP from other activities potentially affecting salinity concentrations in the river. Drainage from GBP was assumed as the only drainage relevant to project-related changes in salt load on the San Joaquin River. The analysis was cast in terms of theoretical dilution water needed to bring the GBP discharges to the Vernalis seasonal EC objectives.

The salinity objectives for Vernalis are 1,000 μS/cm (640 mg/L Total Dissolved Solids) in the winter months (September-March) and 700 μS/cm (448 mg/L TDS) in the summer months (April-August). Figure 1 shows the theoretical volume of water that would be needed to dilute the combined salt loads from the GDA, measured at Station B, and the regional watershed, drained by Mud Slough and Salt Slough (Stations D & F), to meet the Vernalis standards. This analysis does not take into account any of the other operational criteria, nor does it consider salinity contributions to the River other than those derived from the GDA. The value of the analysis is that it permits a "with" and "without" project comparison with prior year hydrology, in terms (water quality releases from a reservoir) meaningful to water users and managers.

The assimilative capacity analysis considers the total volume of dilution water (assumed to have a salinity of 100 ppm) that would be needed to reduce the drainage water alone to the salinity objective. Note that the monthly volume of dilution water is highly dependent on the 100-ppm assumption. Note also that the relation between dilution water quality and required volume is non-linear.

Figure 1 shows the monthly theoretical dilution requirements for WY 1986 through 2002. Figure 2 shows the total theoretical dilution requirement for each water year. The unshaded areas in Figures 1 and 2 represent the theoretical dilution requirements for salt loads generated by the Mud and Salt Slough watershed which includes the GDA and other agricultural areas, wetlands, and uncontrolled runoff from the Coast Range watersheds. The shaded area in the Figures shows the theoretical dilution requirements for salt loads discharged from only the GDA.

The data for Figure 2 are summarized in Tables 4a and 4b. During the 2002 WY, about 166,400 acre-feet of water would have been required to dilute the 28,400 acre-feet of drainage water discharged from the GDA. In comparison, approximately 415,900 acre-feet of water would have been needed to dilute the 185,140 acre-feet of regional discharges to meet the Vernalis standards. The 2002 WY theoretical dilution requirement for the GDA is about 43 percent less than that required during the years prior to the implementation of the GBP Table 4b). The WY 2002 theoretical dilution requirement for the region was eight percent less than that required during the years prior to implementation of the GBP.

These percentages should be put into context of the 1990 – 1994 drought and the initiation of CVPIA water deliveries to wetlands (private, State and Federal) in the Grasslands Basin that preceded the authorization of the Grassland Bypass Project. The latter has profoundly affected the hydrology of the Grasslands Basin and has affected the timing of salt loading to the San Joaquin River.

The allocation to federal contractors in WY 2002 was 65 percent. Data for the GDA for WY 1986 to 2002 show that between WY 1999 and 2002, the salt loads (Tables 3a and 3b) and theoretical dilution requirements (Tables 4a and 4b, and Figures 1 and 2) were smaller than in all other years with the exception of the drought years of WY 1991 and 1992.

The theoretical dilution required for the entire region in WY 2002 was 21 percent less than the average of all prior years and about 30 percent less than the average of water years with above normal water years (Table 4b).

WY 1999 through 2002 had no unusual or unexpected hydrologic events as occurred in WY 1997 and WY 1998. As listed in Table 2a, CVP irrigation deliveries during WY 1999 – 2002 were lower than the WY 1997 and 1998, and the volume of water discharged from the GDA continued to be comparable to that discharged during the drought years of 1991 and 1992.

Data for several more years will be necessary before the impact of the GBP on the San Joaquin River can be quantified with confidence.

Calculations

The formula for theoretical dilution is:

Q2= Q1(C3-C1)/(C2-C3)
Q1 = Drainwater discharge in acre-feet per month
Q2 = Volume of water needed to dilute Q1 to meet Vernalis standards in acre-feet per month
C1 = Measured concentration of GBP drainage water in parts per million (mg/L)
C2 = Assumed concentration of dilution water = 100 mg/L
C3 = Vernalis standard concentration = 448 mg/L April – August, 640 mg/L September - March

References

U.S. Bureau of Reclamation and the San Luis & Delta-Mendota Water Authority. September 28, 2001. Agreement for Use of the San Luis Drain. Agreement No. 01-WC-20-2075.

U.S. Bureau of Reclamation, et. al. June 2002. Monitoring Program for the Operation of the Grassland Bypass Project, Phase II October 1, 2001 – December 31, 2009.

U.S. Bureau of Reclamation, et. al. August 22, 2002. Quality Assurance Project Plan for the Compliance Monitoring Program for the Use and Operation of the Grassland Bypass Project.

Table 1a. Comparison of Flows and Salt Loads Discharged by the Grassland Bypass Project to the San Joaquin River, October 2001 - December 2002

	Discharged from GDA Station B acre-feet	Total Monthly Flow San Joaquin River at Crows Landing Station N acre-feet	B as % of N	Discharged from GDA Station B tons	Total Monthly Salt Load San Joaquin River at Crows Landing Station N tons	B as % of N
Oct-2001	1,100	45,632	2%	4,294	29,550	15%
Nov-2001	1,320	58,918	2%	5,024	39,992	13%
Dec-2001	1,250	58,325	2%	5,308	49,967	11%
Jan-2002	1,660	73,507	2%	7,162	58,572	12%
Feb-2002	2,730	44,321	6%	11,853	58,225	20%
Mar-2002	3,370	53,186	6%	14,892	77,629	19%
Apr-2002	2,430	41,598	6%	11,372	47,247	24%
May-2002	2,640	57,543	5%	11,082	39,690	28%
Jun-2002	3,320	30,054	11%	13,134	35,656	37%
Jul-2002	3,260	25,482	13%	12,749	30,855	41%
Aug-2002	3,410	25,141	14%	11,922	29,466	40%
Sep-2002	1,910	20,256	9%	7,387	20,581	36%
Oct-2002	1,240	38,744	3%	5,213	26,560	20%
Nov-2002	1,150	48,671	2%	4,840	43,994	11%
Dec-2002	1,360	64,739	2%	6,236	59,992	10%
Fifteen month total	32,150	686,117		132,468	647,975	20%

Data Sources: Station B - US Geological Survey Site 11262895
Station N - US Geological Survey Site 11274550

Note: January - March 2002 EC and salt loads at Station N estimated from CVRWQCB autosampler data

Table 1b. Comparison of Flows and Salt Loads Discharged by the Grassland Bypass Project to the San Joaquin River, Water Years 1997 - 2002

	Discharged from GDA Station B acre-feet	Total Flow San Joaquin River at Crows Landing Station N acre-feet	B as % of N	Discharged from GDA Station B tons	Total Salt Load San Joaquin River at Crows Landing Station N tons	B as % of N
WY 1997	37,549	3,844,270	1%	167,739	1,080,703	16%
WY 1998	45,940	4,904,910	1%	205,104	1,511,470	14%
WY 1999	32,310	1,015,350	3%	149,133	680,098	22%
WY 2000	31,260	1,027,480	3%	134,994	703,876	19%
WY 2001	28,254	653,425	4%	120,008	623,555	19%
WY 2002	28,400	556,214	5%	116,180	542,457	21%

Table 1c. Comparison of Flows and Salt Loads Discharged by the Grassland Bypass Project to the San Joaquin River, Calendar Years 1997 - 2002

	Discharged from GDA Station B acre-feet	Total Flow San Joaquin River at Crows Landing Station N acre-feet	B as % of N	Discharged from GDA Station B tons	Total Salt Load San Joaquin River at Crows Landing Station N tons	B as % of N
CY 1997	37,478	3,590,370	1%	169,236	1,072,468	16%
CY 1998	46,240	5,064,280	1%	208,884	1,516,097	14%
CY 1999	32,250	864,520	4%	146,530	664,465	22%
CY 2000	30,210	1,059,222	3%	128,576	689,512	19%
CY 2001	28,014	638,208	4%	119,266	623,841	19%
CY 2002	28,480	523,242	5%	117,842	528,466	22%

Table 2a. Annual Volume of Water Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)	% CVP Contract Delivery (2) acre-feet	Discharge from GDA (3) acre-feet	Discharge from Region (4) acre-feet	GDA discharge as percent of Regional discharge
WY 1986	100%	67,006	284,316	24%
WY 1987	100%	74,902	233,843	32%
WY 1988	100%	65,327	230,454	28%
WY 1989	100%	54,186	211,393	26%
WY 1990	50%	41,662	194,656	21%
WY 1991	25%	29,290	102,162	29%
WY 1992	25%	24,533	85,428	29%
WY 1993	50%	41,197	167,955	25%
WY 1994	35%	38,670	183,546	21%
WY 1995	100%	57,574	263,769	22%
WY 1996	95%	52,978	267,948	20%
WY 1997 GBP	90%	37,549	287,021	13%
WY 1998 GBP	100%	45,940	378,670	12%
WY 1999 GBP	70%	32,310	253,127	13%
WY 2000 GBP	65%	31,260	235,501	13%
WY 2001 GBP	49%	28,254	226,763	12%
WY 2002 GBP	65%	28,400	180,150	16%

Table 2b. Comparison of 2002 WY Discharge Volume to Previous Years

	Water Year	Discharge from GDA (3) acre-feet	WY 2002 difference	WY 2002 difference
Average, all years	1986 - 2002	44,179	-36%	-19%
Prior years average	1986 - 2001	45,165	-37%	-20%
Before GBP average	1986 - 1996	49,757	-43%	-11%
GBP average	1997 - 2002	33,952	-16%	-31%
Below Normal Water Years	(5)	38,668	-27%	-5%
Above Normal Water Years	(6)	49,767	-43%	-30%

Table 2c. Total Volumes of Water

	Water Years	Discharge from GDA (3) acre-feet	Discharge from Region (4) acre-feet	GDA discharge as percent of Regional discharge
All years	1986 - 2002	751,038	3,786,702	20%
Before GBP	1986 - 1996	547,325	2,225,470	25%
GBP total	1997 - 2002	203,713	1,561,232	13%

Notes: Pre-project data compiled by Nigel Quinn (LBNL) from CVRWQCB and USGS reports.

(1) Water Year - October 1 - September 30

(2) Percent of Contract Delivery of CVP water to Delta Division and San Luis Unit

(3) Grassland Drainage Area Station B - US Geological Survey Site 11262895 San Luis Drain

(4) Mud and Salt Sloughs Station D - US Geological Survey Site 11262900 Mud Slough near Gustine
Station F - US Geological Survey Site 11361100 Salt Slough at Hwy 165

(5) Below Normal Water Years with 50% or less CVP delivery: WY 1990 - 1994, 2001

(6) Above Normal Water Years with more than 50 percent CVP delivery: WY 1986 - 1989, 1995 - 2000, 2002

Table 3a. Annual Loads of Salt Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)		% CVP Contract Delivery (2)	Discharge from GDA (3) tons	Discharge from Region (4) tons	GDA load as percent of Regional load
WY 1986		100%	214,250	494,544	43%
WY 1987		100%	241,526	438,904	55%
WY 1988		100%	236,301	455,956	52%
WY 1989		100%	202,420	389,325	52%
WY 1990		50%	171,265	380,564	45%
WY 1991		25%	129,899	221,542	59%
WY 1992		25%	110,327	197,352	56%
WY 1993		50%	183,021	336,522	54%
WY 1994		35%	171,495	379,408	45%
WY 1995		100%	237,530	499,339	48%
WY 1996		95%	197,526	477,725	41%
WY 1997	GBP	90%	167,739	446,693	38%
WY 1998	GBP	100%	205,104	627,687	33%
WY 1999	GBP	70%	149,133	401,614	37%
WY 2000	GBP	65%	134,994	372,452	36%
WY 2001	GBP	49%	120,008	383,155	31%
WY 2002	GBP	65%	116,180	331,596	35%

Data Sources Station B - US Geological Survey Site 11262895 San Luis Drain
Station D - US Geological Survey Site 11262900 Mud Slough near Gustine
Station F - US Geological Survey Site 11361100 Salt Slough at Hwy 165

Table 3b. Comparison of 2002 WY Salt Loads to Previous Years

		Discharge from GDA (3) acre-feet	WY 2002 difference	Discharge from Region (4) acre-feet	WY 2002 difference
Average, all years	1986 - 2002	175,807	-34%	402,022	-18%
Prior years average	1986 - 2001	179,534	-35%	406,424	-18%
Before GBP average	1986 - 1996	190,505	-39%	388,289	-15%
GBP average	1997 - 2002	148,859	-22%	427,200	-22%
Below Normal Water Years	(5)	167,032	-30%	371,690	-11%
Above Normal Water Years	(6)	191,155	-39%	448,712	-26%

Notes: Pre-project data compiled by Nigel Quinn (LBNL) from CVRWQCB and USGS reports.
(1) Water Year - October 1 - September 30
(2) Percent of Contract Delivery of CVP water to Delta Division and San Luis Unit
(3) Grassland Drainage Area Station B - US Geological Survey Site 11262895 San Luis Drain
(4) Mud and Salt Sloughs Station D - US Geological Survey Site 11262900 Mud Slough near Gustine
Station F - US Geological Survey Site 11361100 Salt Slough at Hwy 165
(5) Below Normal Water Years with 50% or less CVP delivery WY 1990 - 1994, 2001
(6) Above Normal Water Years with more than 50 percent CVP delivery WY 1986 - 1989, 1995 - 2000, 2002

Table 4a. Theoretical Annual Volumes of Dilution Water Needed to Meet Vernalis Standards

Water Year (1)		Theoretical Annual Volume of Water Needed to Dilute GDA Discharge to Meet Vernalis Standard (3) acre-feet	Theoretical Annual Volume Water Needed to Dilute Regional Discharge to Meet Vernalis Standard (4) acre-feet
WY 1986		303,361	426,147
WY 1987		332,189	406,134
WY 1988		335,151	424,453
WY 1989		294,834	350,406
WY 1990		245,167	341,299
WY 1991		186,454	235,849
WY 1992		160,419	191,068
WY 1993		272,851	325,964
WY 1994		249,057	363,094
WY 1995		344,983	451,505
WY 1996		283,339	418,393
WY 1997	GBP	246,094	301,219
WY 1998	GBP	302,996	456,678
WY 1999	GBP	216,577	290,092
WY 2000	GBP	195,422	400,730
WY 2001	GBP	174,543	458,769
WY 2002	GBP	124,538	320,031

Table 4b. Comparison of Theoretical Dilution Requirement

		Theoretical Annual Volume of Water Needed to Dilute GDA Discharge to Meet Vernalis Standard (3) acre-feet	WY 2002 difference	Theoretical Annual Volume Water Needed to Dilute Regional Discharge to Meet Vernalis Standard (4) acre-feet
Average, all years	1986 - 2002	251,057	-50%	362,461
Prior years average	1986 - 2001	258,965	-52%	365,112
Before GBP average	1986 - 1996	273,437	-54%	357,665
GBP average	1997 - 2002	210,028	-41%	371,253
Below Normal Water Years	(5)	235,505	-47%	372,679
Above Normal Water Years	(6)	270,862	-54%	385,981

Notes

Pre-project data compiled by Nigel Quinn (LBNL) from CVRWQCB and USGS reports

(1) Water Year - October 1 - September 30

(2) Percent of Contract Delivery of CVP water to Delta Division and San Luis Unit

(3) Grassland Drainage Area

(4) Mud and Salt Sloughs

(5) Below Normal Water Years with 50% or less CVP delivery WY 1990 - 1994, 2001

(6) Above Normal Water Years with more than 50 percent CVP delivery WY 1986 - 1989, 1995 - 2000, 2002

Figure 1. Theoretical Monthly Volumes of Water Needed to Dilute Drainage Water from the Grassland Drainage Area and Regional Watershed to Meet Vernalis Standards October 1986 – December 2002

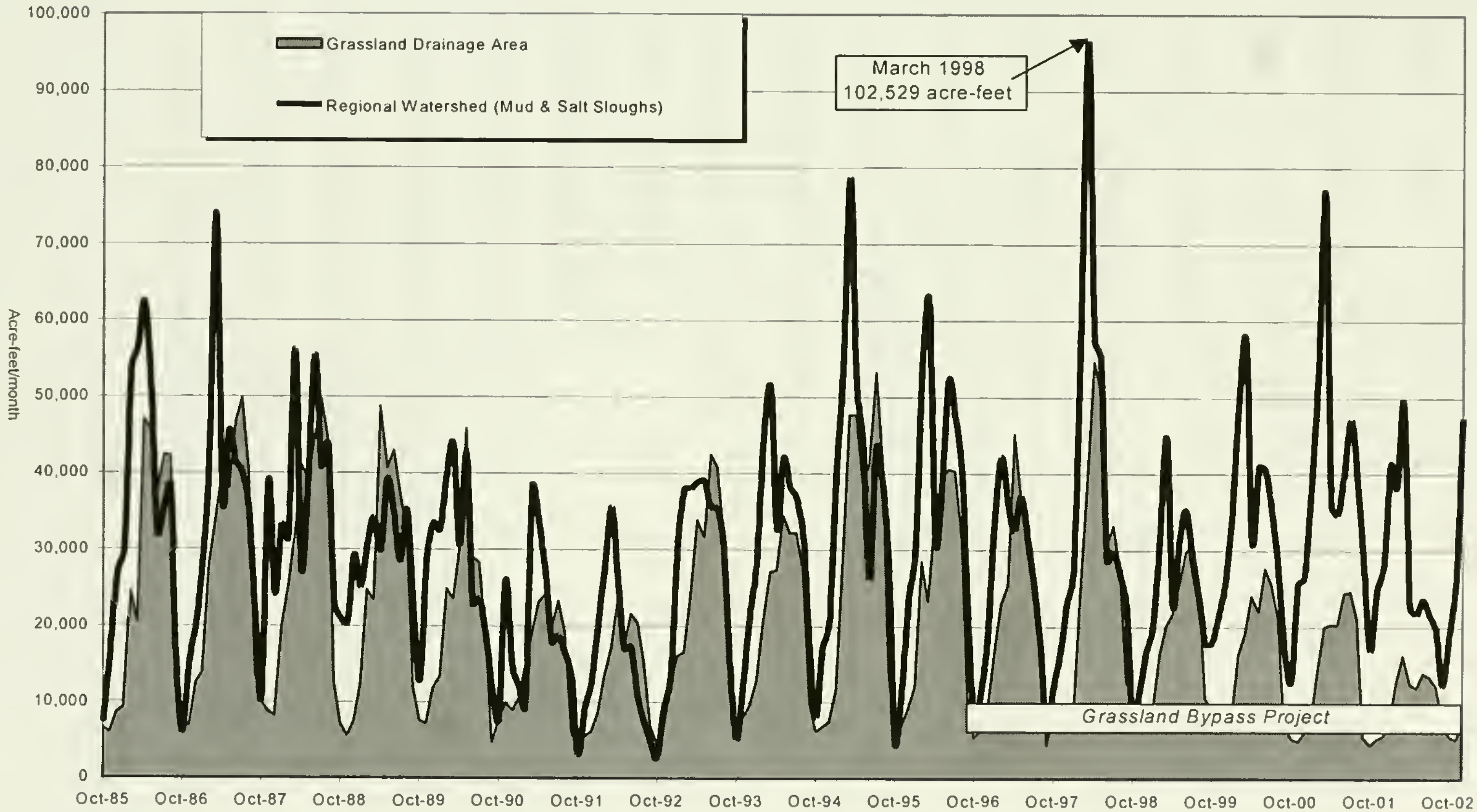
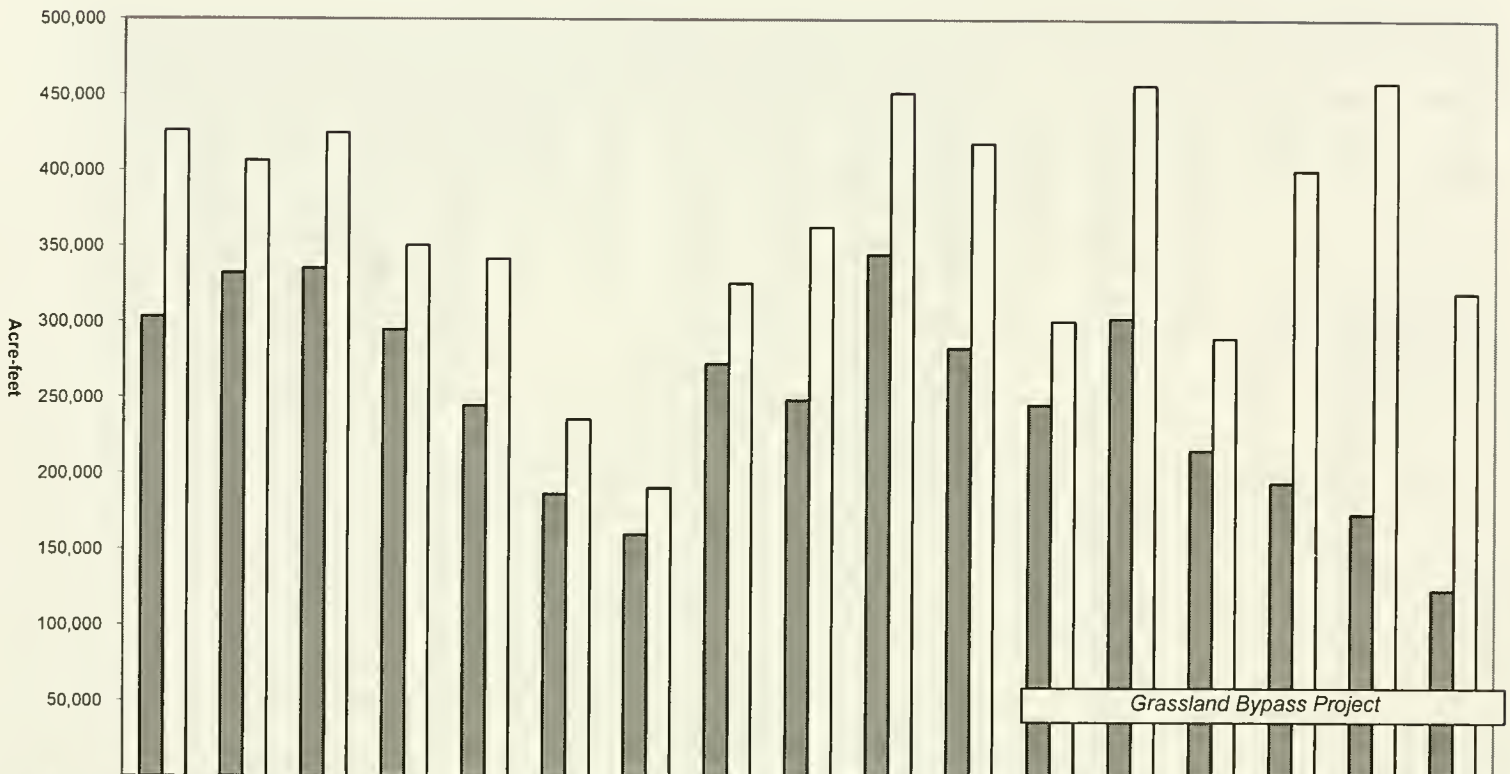


Figure 2 - Theoretical Annual Volumes of Water Needed to Dilute Drainage from the Grassland Drainage Area and the Regional Watershed to Meet Vernalis Standards (1986 - 2002 Water Years)



	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
GDA	303,361	332,189	335,151	294,834	245,167	186,454	160,419	272,851	249,057	344,983	283,339	246,094	302,996	216,577	195,422	174,543	124,538
Regional	426,147	406,134	424,453	350,406	341,299	235,849	191,068	325,964	363,094	451,505	418,393	301,219	456,678	290,092	400,730	458,769	320,031

7

Biological Effects of the Grassland Bypass Project

October 1, 2001 – December 31, 2002

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Abstract

Biological monitoring continued for the Grassland Bypass Project's sixth year of operation at seven sampling sites (Figure 1). Results presented below cover a 15-month period from October 2001 through December 2002. All whole body composite samples (small fish, invertebrates, and vegetation) results are presented as average selenium concentrations (mg/kg) based on dry tissue weight. All muscle tissue composite samples (mainly carp) results are presented as average selenium concentrations (mg/kg) based on wet tissue weight.

Selenium concentrations in whole-body fish and invertebrates sampled in Mud Slough below the outfall of the San Luis Drain (SLD) frequently exceeded thresholds of concern as presented in Table 1. However, for the 15-month period covered in this report, average selenium concentrations of all composite fish samples from Mud Slough sites either decreased significantly (Site D), increased significantly (Site E), or did not change (Site I2) compared to Water Year (WY) 2001.

The first site in Mud Slough contaminated with drainage water from the Grassland Drainage Area is Site D. The concentration of selenium in 18 of 20 composite samples of small fish caught at this site during the fifteen month study period exceeded the 4 mg/kg (dry weight) threshold of concern (Figure 10). The concentration of selenium in inland silversides caught March 2002 and in fathead minnows caught August 2002 exceeded the 9 mg/kg (dry weight) threshold of toxicity (Figure 10). The concentration of selenium in bullfrogs caught in August 2002 was below the 3 mg/kg threshold of concern (Figure 12). The concentration of selenium in red crayfish caught November 2001 exceeded the 3 mg/kg threshold of concern (Figure 13). The overall hazard of selenium to the ecosystem (Lemly's index) continued to be high in the reach of Mud Slough below the SLD outfall (Table 4)

At a backwater site further downstream from the outfall (Site I2), the average selenium concentrations in all 20 composite samples of small fish caught during the fifteen month study period exceeded the 4 mg/kg concern threshold (Figure 14). All four composite samples caught during August 2002 exceeded the 9 mg/kg toxicity threshold (Figure 14). The average concentration of selenium in carp caught in June and August 2002 was slightly below to the 9 mg/kg toxicity threshold; seven samples of Sacramento blackfish collected November 2001 and November 2002 were below the 3 mg/kg threshold of concern (Figure 15). The concentration of selenium in waterboatmen invertebrates caught at this site was above the 3 mg/kg threshold of concern during three of four sampling events (Figure 16). The concentration of selenium in red crayfish caught November 2001 was above the 7 mg/kg threshold of toxicity; the concentration of selenium in red crayfish caught one year later was lower, but above the 3 mg/kg threshold of concern (Figure 16).

At a site further downstream in Mud Slough just above its confluence with the San Joaquin River, (Site E), selenium in whole-body fish exceeded the 9 mg/kg threshold of toxicity on four of five sampling events during the fifteen month study period (Figure 17). The concentration of selenium in red crayfish exceeded the threshold of toxicity in samples collected in August and December 2002 (Figure 18). The selenium concentrations in carp muscle tissue collected at this site during November 2001 and August 2002 exceeded the 2 mg/kg (wet weight) human health consumption guideline (Figure 27).

At a sampling site on Mud Slough above the outfall (Site C), the selenium concentration of nine of seventeen samples of small fish collected at this site were above the 4 mg/kg concern threshold (Figure 6). The concentration of selenium in medium-sized fish, bullfrogs, and invertebrates remained within the no-effect level (Figures 7, 8, and 9).

In Salt Slough, where drainwater has been removed by the GBP, average selenium concentrations in small and medium fish and invertebrates remained at no-effect levels during the fifteen month study period (Figures 2, 3 and 5). The concentration of selenium in bullfrogs caught August 2002 exceeded the 4 mg/kg threshold of concern (Figure 4). The overall hazard of selenium to the ecosystem (Lemly's index) was low in Salt Slough (Table 4).

In the San Joaquin River upstream (Site G) of the Mud Slough discharge, selenium concentrations in whole-body fish remained below the concern threshold of 4 mg/kg (dry weight) (Figure 19). Selenium concentrations in all invertebrates collected from this site remained below the 3 mg/kg (dry weight) threshold of concern for invertebrates as prey items (Figure 20). The selenium concentration in all carp muscle tissues collected at this site during the fifteen month study period were below the 2 mg/kg (wet weight) human health consumption guideline (Figure 28).

However, in the San Joaquin River downstream of the Mud Slough discharge (Site H), selenium concentrations in whole-body fish exceeded the concern threshold of 4 mg/kg (dry weight) in samples collected in March and December 2002 (Figure 21). Selenium concentrations in red crayfish collected from this site exceeded the 3 mg/kg (dry weight) concern threshold in samples collected in November 2001 and December 2002 (Figure 22). The concentration of selenium in all samples of carp muscle tissue collected at this site during the fifteen month study period was below the 2 mg/kg (wet weight) human health consumption guideline (Figure 29).

The selenium concentrations in all bird eggs collected during the fifteen month study period in the Salt Slough area and the Mud Slough area were within the no effect range (Figure 31).

Selenium concentrations in seeds collected at sites C, F and I2 in August 2002 were below the analytical reporting limit of 0.2 mg/kg (dry weight). The concentration of selenium in swamp timothy seed heads collected at Site D in August 2002 was above the 3 mg/kg threshold of concern as diet for birds. All seed samples collected at sites E, G and H were within the dietary no-effect level as diet for birds (Figure 30).

The boron concentration in one composite seed sample from the bank of Salt Slough was just slightly above the threshold of concern. The boron concentration in one of three plant samples collected from Mud Slough sites below the SLD outfall was above the 30 mg/kg (dry weight) threshold of concern. Both composite seed samples collected along Mud Slough above the outfall (Site C) were above the boron threshold of concern. The boron concentration in all samples collected from the San Joaquin River near Fremont Ford (Site G) was below the 30 mg/kg (dry weight) threshold of concern. The concentration of boron in seeds collected at the San Joaquin River at Hills Ferry (Site H) was above the 30 mg/kg (dry weight) threshold of concern.

Introduction

Project History

In 1985 the SLD was closed due to deaths and developmental abnormalities of waterbirds at a reservoir in the Kesterson National Wildlife Refuge at the terminus of the SLD. The SLD, constructed by the U.S. Bureau of Reclamation (USBR), had been conceived as a means to dispose of agricultural drainwater generated from irrigation with water supplied by the federal Central Valley Water Project. However, due to environmental concerns and budget constraints, the SLD had never been completed as originally planned. The constructed portion of the SLD had been used only to convey subsurface agricultural drainwater from the Westlands Water District in the western San Joaquin Valley. Farms in the adjacent Grassland Drainage Area (GDA) never used the SLD, but discharged subsurface drainwater through wetland channels in the Grassland Water District, San Luis National Wildlife Refuge Complex, and the China Island Unit of the North Grasslands Wildlife Area (Refuges) to the San Joaquin River. This drainwater contains elevated concentrations of selenium, boron, chromium, and molybdenum, and high concentrations of various salts (CEPA, 2000) that disrupt the normal ionic balance of affected aquatic ecosystems (SJVDP, 1990b).

Discharge from GDA farms was unaffected by the closure of the SLD, and drainage continued to contaminate Refuge water delivery channels after the closure of the SLD and Kesterson Reservoir in 1986. To address this problem, a proposal to use a portion of the SLD and extend it to Mud Slough, a natural waterway in the Refuges, was implemented by the USBR in September 1996 with support from other federal and state agencies (USBR, 1995; USBR and SLDMWA 1995; USBR et al., 1995). This project, known as the Grassland Bypass Project (GBP), diverts agricultural drainwater from GDA farms into the lower 28 miles of the SLD and thence into the lower portion of Mud Slough (about six miles). The GBP has removed drainwater from more than 90 miles of wetland water supply channels, including Salt Slough, and allows the Refuges full use of water rights to create and restore wetlands on the Refuges. The GBP, as currently implemented, continues to affect the northernmost six miles of Mud Slough and the reach of the San Joaquin River between Mud Slough and the Merced River. However, as phased-in load reduction goals are achieved by GDA farmers, these effects are expected to be reduced. An essential component of the GBP is a monitoring program that tracks contaminant levels and effects in water, sediment, and biota to ensure that the overall effect of the GBP is not a net deterioration of the ecosystems in the area affected by the GBP.

Contaminants of Concern

In the aftermath of the deaths and developmental abnormalities of birds at Kesterson Reservoir in the early 1980s, studies definitively traced the cause to selenium in the agricultural subsurface drainwater in the reservoir (Suter, 1993). Because of this, and because of the well-known history of death, teratogenesis, and reproductive impairment caused by selenium in agricultural drainwater elsewhere (reviewed in Skorupa, 1998), the primary contaminant of concern in this monitoring program is selenium. Other inorganic constituents of potential toxicological interest in drainage water include boron, molybdenum, arsenic and chromium (Klasing and Pilch, 1988; SJVDP, 1990a; CVRWQCB, 1998).

Selenium Ecological Risk Guidelines

The assessment of the risks that selenium poses to fish and wildlife can be difficult due to the complex nature of selenium cycling in aquatic ecosystems (Lemly and Smith, 1987). Early assessments developed avian risk thresholds through evaluating bird egg concentrations and relating those to levels of teratogenesis (developmental abnormalities) and reproductive impairment (Skorupa and Ohlendorf, 1991). In 1993, to evaluate the risks of the Grassland Bypass Project on biotic resources in Mud and Salt Sloughs, a set of Ecological Risk Guidelines based on selenium in water, sediment, and residues in several biotic tissues were developed by a subcommittee of the San Luis Drain Re-Use Technical Advisory Committee (CAST, 1994; Engberg, et.al., 1998). These guidelines (as recently modified: Table 1) are based on a large number of laboratory and field studies, most of which are summarized in Skorupa et al. (1996) and Lemly (1993). In areas where the potential for selenium exposure to fish and wildlife resources exists, these selenium risk guidelines can be used to trigger appropriate actions by resource managers, regulatory agencies, and dischargers. For the GBP the selenium risk guidelines have been divided into three threshold levels: No Effect, Concern, and Toxicity.

In the No Effect range risks to sensitive species are not likely. As new information becomes available it should be evaluated to determine if the No Effect level should be adjusted. Since the potential for selenium exposure exists, periodic monitoring of water and biota is appropriate.

Within the Concern range there may be risk to species sensitive to elevated contaminant concentrations in water, sediment, and biota, and should be monitored on a regular basis. Immediate actions to prevent selenium concentrations from increasing should be evaluated and implemented if appropriate. Long-term actions to reduce selenium risks should be developed and implemented. Research on effects on sensitive or listed species may be appropriate.

Within the Toxicity range, adverse affects are more likely across a broader range of species, and sensitive or listed species would be at greater risk. These conditions will warrant immediate action to reduce selenium exposure through disruption of pathways, reduction of selenium loads, or other appropriate actions. More detailed monitoring, studies on site-specific effects, and studies of pathways of selenium contamination may be appropriate and necessary. Long-term actions to reduce selenium risks should be developed and implemented.

The guidelines (except those for avian eggs) are intended to be population based. Therefore they should be used for evaluating population means rather than contaminant concentrations in individuals.

Warmwater Fish

The warmwater fish guidelines (Table 1) refer to concentrations of selenium in warmwater fish that adversely affect the fish themselves. The original 1993 fish guidelines have been replaced by explicitly "warmwater fish" guidelines in recognition of the evidence from the literature that coldwater fish (salmon and trout) are more sensitive to selenium than warmwater fish and that GBP monitoring data available is limited to warmwater fish. Although a coldwater fish guideline is not proposed here, a discussion of selenium effects on coldwater fish is provided in this section since the best information currently available happens to be very site-specific to the GBP area (Merced River and downstream San Joaquin River).

The concern threshold for warmwater fish has been kept at 4 mg/kg (all fish data are whole body, dry weight). Experimental data reported in the literature may be interpreted to support a range of thresholds around this value. In particular, bluegill sunfish dietary and waterborne toxicity data in Cleveland et al. (1993) can be used to support warmwater fish concern thresholds of 3.3 mg/kg, 3.4 mg/kg, 3.9 mg/kg, or 5.9 mg/kg. Bluegill sunfish are warmwater fish that are found in the sloughs in the GBP area, and the Cleveland et al. (1993) study yielded the best available data on warmwater fish toxicity applicable to GBP.

Cleveland et al. (1993) found no adverse effects after 59 days of exposure to concentrations of dietary selenium that resulted in a bluegill tissue concentration of 2.7 mg/kg (NOEC). Fifty nine days of exposure to dietary concentrations that resulted in tissue concentrations of 4.2 mg/kg (LOEC) caused a significant increase in mortality relative to controls. Following the USEPA method (Stephan et al., 1985) employed by DeForest et al. (1999), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. Application of the USEPA procedure to these data yields a toxicity threshold of 3.4 mg/kg. A similar analysis of a water-borne selenium exposure experiment (Cleveland et al., 1993) yields a threshold value of 3.3 mg/kg.

Other data in Cleveland et al. (1993) may be interpreted to support a threshold closer to 4 mg/kg or a threshold of 5.9 mg/kg. The experiments of Cleveland et al. (1993) suggest that selenium concentrations in fish tissues do not reach equilibrium until at least 90 days of dietary exposure (Figure 3 in Cleveland et al., 1993). This appears consistent with the finding, summarized below, that in the field, selenium concentrations in fish are best predicted by water concentrations averaged over the entire period of one to seven months prior to the date the fish is sampled. In deriving a tissue threshold, there then appears to be some support for using the relationship between dietary concentration and tissue concentration at 90 days rather than 59 days. After 90 days of dietary exposure bluegill with a tissue selenium concentration of 3.3 mg/kg did not exhibit adverse effects that were significantly greater than controls, but bluegill with a tissue concentration of 4.6 mg/kg experienced significantly increased mortality. Bluegill with a tissue concentration of 7.5 mg/kg had three times the mortality of controls, but that difference in mortality was not statistically significant at the 95% level of confidence (Table 4 and Figure 3 in Cleveland et al., 1993). However, the condition factor (a measure of weight relative to length) of the fish at 7.5 mg/kg, was significantly worse than controls. Depending on whether or not the significant mortality at a tissue concentration of 4.7 mg/kg is treated as anomalous, the LOEC would be either 4.7 mg/kg or 7.5 mg/kg. Corresponding thresholds would be 3.9 mg/kg (geometric mean of 3.3 mg/kg and 4.6 mg/kg) or 5.9 mg/kg (geometric mean of 4.6 mg/kg and 7.5 mg/kg) respectively. Given the range of possible threshold values discussed above, the concern threshold of 4 mg/kg listed in Table 1 was not changed from the original 1993 threshold. However, considering that these data do not include adverse effects on reproduction which that may occur at lower concentrations, this threshold may not be fully protective of sensitive warmwater fish species.

The toxicity threshold for warmwater fish (whole body) of 9 mg/kg is recommended by DeForest et al. (1999). In the analysis of DeForest et al. (1999) the threshold represents an EC10, that is, the concentration at which 10 percent of fish are affected. DeForest et al. (1999) excluded some toxicity data from their analysis that could support a lower threshold (Cleveland et al., 1993). Also, reproductive impairment may occur at lower selenium concentrations, but

too few data are available to do a similar analysis on this effect. Therefore, this Toxicity threshold may not be fully protective of sensitive warmwater fish species.

Coldwater Fish

Testing fall run chinook salmon from the Merced River, Hamilton et al. (1990) found that salmon fry growth was significantly reduced compared to controls after 30 and 60 days of being fed a diet (containing mosquitofish from the SLD) having a selenium concentration of 3.2 mg/kg dry weight. After 90 days of that diet, the selenium concentration in the salmon fry averaged 2.7 mg/kg whole body, dry weight. This fish tissue concentration was the lowest observable effect concentration (LOEC) The no observable effect concentration (NOEC) in salmon fry tissue was 0.8 mg/kg. Following the USEPA method (Stephan et al., 1985) employed by DeForest et al. (1999), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. This procedure applied to the Hamilton et al. (1990) SLD data yields a threshold of 1.5 mg/kg (geometric mean of 0.8 and 2.7 mg/kg). It should be noted that this threshold may incorporate the interacting effects of other toxic constituents of drainwater that may have been assimilated by the SLD mosquitofish that were used as feed in the Hamilton, et al.(1990) experiments. Furthermore, at the time of these experiments (1985), the SLD held agricultural drainwater from the Westlands, an area adjacent to the Grasslands area. Therefore, although these are the most site-specific selenium toxicity data available, these data may not perfectly match the current risk of toxicity to coldwater fish in the San Joaquin River due to agricultural drainwater from the GBP. Although the sloughs affected by the GBP have coldwater beneficial uses designated by the Central Valley Regional Water Quality Control Board, the fish community principally consists of warmwater species. A temporary barrier is installed seasonally across the San Joaquin River to exclude chinook salmon (a coldwater species) from these sloughs and from the San Joaquin River upstream of its confluence with the Merced River. Additionally, any application of the coldwater fish risk guidelines should take into account the fact that many coldwater fish are anadromous, and therefore feed in the selenium-contaminated portion of the San Joaquin River for a limited period of time-- a brief period in their juvenile stage as they migrate downstream to the ocean.

A toxicity threshold for coldwater fish (whole body) of 9 mg/kg has been recommended by DeForest et al. (1999). In their analysis, the toxicity threshold represents an EC10, that is, the concentration at which 10 percent of fish are affected. DeForest et al. (1999) excluded site-specific and longer term data (Hamilton et al., 1990) which could support lower thresholds. For example, to derive their toxicity threshold for coldwater fish, DeForest et al. (1999) used only the 60 day growth data in Hamilton et al. (1999); they disregarded the 90 day mortality data in Hamilton et al. (1999) that would have yielded a toxicity threshold (corresponding to10% mortality) of 1.7 mg/kg. In addition, the DeForest et al. (1999) analysis focused on growth and mortality. Reproductive impairment may occur at lower selenium concentrations, but too few data are available to do a similar analysis on this effect. Therefore, this threshold may not fully protect sensitive coldwater fish species.

Vegetation and Invertebrates

The guidelines for vegetation (as diet) and invertebrates (as diet) refer to selenium concentrations in plants and invertebrates affecting birds that eat these items. These guidelines are mainly based on experiments in which seleniferous grain or artificial diets spiked with selenomethionine were fed to chickens, quail or ducks resulting in reproductive impairment

(Wilber, 1980; Martin, 1988; Heinz, 1996). The Concern threshold for vegetation is 3 mg/kg (dry weight) and the Toxicity threshold is 7 mg/kg. The invertebrate concern threshold and toxicity threshold are the same as those for vegetation.

Water

Fish and wildlife are much more sensitive to selenium through dietary exposure from the aquatic food chain than by direct waterborne exposure. Therefore the guidelines for water reflect water concentrations associated with threshold levels of food chain exposure (Hermanutz et al., 1990; Maier and Knight, 1994), rather than concentrations of selenium in water that directly affect fish and wildlife. The concern threshold is 2 μg/L and the toxicity threshold is 5 μg/L.

Sediment

As with water, the principal risk of sediment to fish and wildlife is via the aquatic food chain. Therefore the sediment guidelines are based on sediment concentrations as predictors of adverse biological effects through the food chain (USFWS, 1990; Van Derveer and Canton, 1997). The concern threshold for sediment (dry weight) is 2 mg/kg and the toxicity threshold is 4 mg/kg.

Bird Eggs

Bird eggs are particularly good indicators of selenium contamination in local ecosystems (Heinz, 1996). However, the interpretation of selenium concentrations in bird eggs in the GBP area is complicated by the proximity of contaminated and uncontaminated sites and by the variation in foraging ranges among bird species. Relative to the guidelines originally used for the GBP, the guidelines used here for individual bird eggs have been revised upward based on recent studies of hatchability of ibis, mallard, and stilt eggs (Henny and Herron, 1989; Heinz, 1996; USDI-BOR/FWS/GS/BIA, 1998). The concern threshold has been raised from 3 to 6 mg/kg dry weight, and the toxicity threshold has been raised from 8 to 10 mg/kg dry weight.

Selenium Ecological Risk Index

Several years after the risk guidelines were developed for the GBP, Lemly (1995, 1996) published a risk index designed to provide an estimate of ecosystem-level effects of selenium. Lemly's assessment procedure sums the effects of selenium on various ecosystem components to yield a characterization of overall hazard to aquatic life. The procedure involves determining an index of toxicity for each component, then adding these indexes together to yield a single index, often known as the Lemly Index. In contrast to the ecological risk guidelines outlined in Table 1, the component indexes of the Lemly Index are based on maximum contaminant concentrations rather than means. Therefore, the Lemly Index is sensitive to brief spikes in contaminant levels, but is unaffected by prevailing contaminant levels. Furthermore, the Lemly Index is strongly dependent on sampling periods and sampling frequency, yet Lemly provided no sampling protocol. For these reasons, there is a need to develop a new protocol and index that replaces Lemly's categorical rating format (low, medium, high) with a direct estimate of the probability of adverse effects (e.g.10%+ probability of reproductive impairment). Despite the weaknesses of the Lemly Index, we continue to use it for comparative purposes as long as it remains the best available overall index of the ecological risk of selenium.

Boron Ecological Risk Guidelines

The dietary and tissue concentrations of boron associated with toxic effects on fish and wildlife are not as well known as for selenium. The effects of dietary exposures and waterborne exposures (without dietary exposures) are known for some taxa (Table 2), but there are as yet no definitive data associating tissue concentrations with adverse effects in fish and invertebrates. Boron concentrations as low as 0.1 mg/l in water may adversely affect reproduction of sensitive fish species (review in NIWQP, 1998).

Methods

The role of the California Department of Fish and Game (CDFG) and the United States Fish and Wildlife Service (USFWS) in this interagency program is to implement the bio-monitoring portion of the Compliance Monitoring Program. The methods used by the CDFG and USFWS are described in the Quality Assurance Project Plan for Use and Operation of the Grassland Bypass Project (QAPP; Entrix, Inc., 1997). These methods are also based on standard operating procedures described in Standard Operation Procedures for Environmental Contaminant Operations (USFWS, 1995) and standards used by the other agencies participating in the compliance monitoring program. Deviations from the QAPP that have occurred since 1996 will be discussed later in this section.

To obtain baseline data for this Project, the USFWS began sampling in March 1992, after the reuse of the SLD was initially proposed by the USBR in 1991. The CDFG began sampling in August of 1993. USFWS and CDFG sampling plans before the reopening of the SLD and the early drafts of the monitoring plan were mutually influencing. Therefore, methods used by both agencies before the final approval of the QAPP are, except for a few minor differences, identical to the methods ultimately approved by the Data Collection and Reporting Team. The sampling schedule, though, as discussed below, now follows a regular timetable.

Due to the 2001 Waste Discharge Requirement Monitoring and Reporting Order, this report covers a fifteen month study period between October 2001 and December 2002.

Matrices Sampled

Samples of the biota were collected at each site and analyzed for selenium and boron. Aquatic specimens were collected with hand nets, seine nets and by electro fishing. Mosquitofish (Gambusia affinis), inland silversides (Menidia beryllina), red shiners (Cyprinella lutrensis), fathead minnows (Pimephales promelas), carp (Cyprinus carpio), white catfish (Ameiurus catus), and green sunfish (Lepomis cyanellus) were the principal species of fish collected. Waterboatmen (family: Corixidae), backswimmers (family: Notonectidae), and red crayfish (Procambarus clarkii) were the principal invertebrates collected. Separation of biological samples from unwanted material also collected in the nets was accomplished by using stainless steel or Teflon sieves, and glass (or enamel) pans pre-rinsed with de-ionized water then native water. To the extent possible, three replicate, composite samples (minimum 5 individuals totaling at least 2 grams for each composite) of each primary species listed above were collected, but other species were also collected. Fish species were analyzed as composite whole-body samples except as noted below. Estimates of a conversion factor for relating selenium

concentration in skeletal muscle (M) to whole-body concentrations (WB) range from M=0.6xWB for many freshwater fish (Lemly and Smith, 1987) to M=0.045+1.23xWB for bluegills and M=-0.39+1.32xWB for largemouth bass (Saiki et al., 1991).

Between 1992 and 1999, frog tadpoles occasionally collected from Mud Slough and Salt Slough sites were archived. In 1999 these archived samples were analyzed. Additional samples were collected and analyzed from these sites in 2000 and 2001.

Analyses of fish samples collected from the San Joaquin River (Sites G and H) and Mud Slough (Sites C, D, 12 and E) were prioritized to first meet the objectives of the Compliance Monitoring Plan (Section 4.5.1.4). Supplemental fish samples were analyzed only when baseline biota target species and sample sizes could not be obtained.

In WY 1999, 2000, and 2001 several samples of fish and invertebrates submitted for analysis were of insufficient mass to permit individual measurement of the water content (percent moisture) of the sample, a measurement used to calculate the dry weight selenium concentration in the sample. For these samples (designated with asterisk on the graphs), an average percent moisture was calculated from the percent moisture measurements of comparable samples in the closest possible conditions of sampling location, time, species, and size of organism. This average percent moisture was used to calculate the dry weight selenium concentration. Selenium concentrations discussed in text and displayed in figures below are averages of composite sample concentrations except for bird eggs and except where otherwise stated.

The seed heads of wetland plants that provide food for waterfowl were collected along the sloughs in the late summer of the years 1995-2002. This plant material was archived for later analysis.

Waterfowl and/or shorebird eggs, depending on availability, were collected from areas adjacent to Mud Slough and the SLD in the spring of each year from 1996 through 2002. In addition, in 1992 snowy egret and black-crowned night heron eggs were collected at East Big Lake, which has served as a reference sampling site for the USFWS. Bird eggs were analyzed individually, and the results are discussed and displayed below as individual concentrations and geometric means.

Graphs of whole-body and avian egg selenium concentrations presented in this report include indications of the threshold concentrations delimiting the risk ranges listed above (Table 1). The threshold between the No Effect Zone and the Concern Zone is indicated by a horizontal line of short dashes; the Toxicity threshold is marked on each graph by a horizontal line of long dashes.

All biota samples were kept on ice or on dry ice while in the field then kept frozen to Zero degrees centigrade C during storage and shipment. For all samples, after freeze drying, homogenization, and nitric-perchloric digestion, total selenium was determined by hydride generation atomic absorption spectrophotometry and boron was determined by inductively coupled (argon) plasma spectroscopy.

Sampling Sites

Between 1992 and 1999 biological samples have been collected from two sites on Salt Slough, five sites on Mud Slough, two sites in the SLD, two sites on the San Joaquin River, and

one reference site that does not receive selenium-contaminated drainwater (East Big Lake). Beginning in 1995, sampling efforts were concentrated on the seven sites (Figure 1) identified in the Compliance Monitoring Plan: four sites on Mud Slough (C, D, E, and I), one on Salt Slough (F) and two San Joaquin River sites (G and H). Site C is located upstream of where the Grassland Bypass discharges into Mud Slough. Site D is located immediately downstream of the discharge point. Site I is a small, seasonally flooded backwater area fed by Mud Slough and is located approximately 1 mile downstream from Site D. Site E is located further downstream where Mud Slough crosses State Highway 140. To assess the mitigative effects of drainwater removal from Salt Slough, one sample point, Site F, is located on the San Luis National Wildlife Refuge approximately 2 miles upstream of where State Highway 165 crosses Salt Slough. Site G is located on the San Joaquin River at Fremont Ford, upstream of the Mud Slough confluence, while Site H is located on the San Joaquin River 200 meters upstream of the confluence of the main branch of the Merced River, downstream of the Mud Slough confluence. Sites C, D, F, and I are monitored by the USFWS while CDFG monitored Sites E, G, and H.

During the WY 2001, biological sampling in Mud Slough was moved from Site I to a new site (Site I2) about 0.5 km upstream of Site I. The new site has a larger, more permanent backwater area.

Sampling Times

Baseline sampling conducted by the USFWS occurred monthly during the spring and summer of 1992 and then less frequently during 1993 and 1994. Baseline sampling by CDFG occurred during the summer and fall of 1993 and then resumed in the spring of 1996. Between 1992 and 1995 sampling by either the CDFG and the USFWS occurred at least once every season. Experience and interagency discussions led to the identification of four sampling times based on historic water use and drainage practices and on seasonal use of wetland resources by fish and wildlife. Biota sampling since 1995 has been synchronized to occur during the months of November, March, June, and August. Since 1996, avian eggs have been collected in May and June.

Due to the 2001 Waste Discharge Requirement Monitoring and Reporting Order, this report covers a fifteen month study period between October 2001 and December 2002.

Statistical Analysis

Student's 2-tail t-tests were used to compare means of concentrations for groups of samples collected at different times at the sampling sites (unpaired samples with unequal variances).

Selenium Hazard Assessment

The protocol proposed by Lemly (1995, 1996) was used to estimate the overall hazard of selenium to the ecosystems affected by the GBP. The implementation of the protocol presented here incorporates data for water from Central Valley Regional Water Quality Control Board and data for sediment from the USBR in addition to biological data collected by the USFWS, CDFG, and CH2M HILL. In accordance with Lemly's protocol, the assessments use the highest (rather than the mean) concentrations of selenium found in each of the ecosystem components (Tables 1 and 5).

Data from the biological sampling in November 1996, shortly after GBP initiation, were excluded from the WY 1997 hazard assessments because temporarily extremely high concentrations of selenium in some fish may have been due to those fish having been flushed out of the previously stagnant, evapo-concentrated SLD. Very high levels of selenium in the water associated with storm flows were not excluded because elevated concentrations persisted long enough (especially in February 1998) potentially to affect the ecosystem adversely.

Concentrations of selenium in fish eggs were estimated from whole-body concentrations using the conversion factor (fish egg selenium = fish whole-body selenium x 3.3) recommended in Lemly (1995, 1996).

In this report, care has been taken to ensure that Lemly index for the area potentially adversely affected by the Grassland Bypass Project incorporates only contaminant levels that are due to this project. Therefore, although Figure 31 displays selenium concentrations in killdeer eggs collected along the San Luis Drain in the Kesterson Reservoir area, those data are not used in the calculation of the Lemly index because of the possibility that some of the most elevated selenium concentrations in eggs are due to killdeer foraging in areas of the Kesterson Reservoir residually contaminated by selenium from Westlands area farms predating this project.

Site E (lower Mud Slough) and the San Joaquin River (SJR) sites (G and H) cannot be rated as to overall hazard of selenium because not all media have been collected to assess these sites. Further confounding the evaluation at these sites is the prevalence of introduced fish species with broad environmental tolerances and the limited catch of invertebrates during WY 1999 and WY 2000.

Departures from the Compliance Monitoring Plan and Quality Assurance Project Plan

To ensure reliable and consistent data, the USFWS and the CDFG followed the procedures specified in the Compliance Monitoring Plan and the Quality Assurance Project Plan (QAPP) with the exceptions listed below.

External quality assurance samples (QAPP Appendix A, Section 7) were not submitted to analytical labs with GBP biological samples before January of 1998. External quality assurance samples are biological materials (e.g. powdered chicken egg, shark liver) with certified concentrations of the analytes of concern (selenium, boron), supplied by third party laboratories. The analyte concentrations in these samples are known to the agencies submitting the samples, but not known to the laboratory doing the analysis. This blind test of laboratory analytical precision supplements the internal quality control procedures of the analytical laboratory. Internal quality control protocols specified in the QAPP (procedural blanks, duplicate samples, and spiked samples) have been followed throughout the history of GBP biological sampling.

The USFWS used stainless steel (rather than Teflon) strainers for sorting small fish (QAPP Appendix A, Section 4.7).

For some species at some locations it has not been practical at some times to collect the full target minimum numbers of individuals and/or mass per sample that are specified in the Compliance Monitoring Plan (Section 4.5.1.4) and the QAPP (Appendix A, Section 4.5).

From 1992 through 1997 all biological samples collected by the USFWS (except bird eggs in 1996 and 1997) were analyzed by Environmental Trace Substance Laboratory at the University of Missouri in accordance with the QAPP (Appendix A, Section 6.1). Bird egg

samples collected in 1996 and 1997 were analyzed at Trace Element Research Laboratory (TERL) at Texas A & M University, a USFWS contract laboratory. All biological samples collected in 1998 were analyzed at TERL. TERL is subject to the same performance standards as Environmental Trace Substance Laboratory, therefore, the GBP quality assurance objectives (QAPP Table 1) apply to analytical results from TERL. All biological samples beginning in 1999 have been analyzed at the Water Pollution Control Laboratory of the CDFG in Rancho Cordova, California, after this laboratory was screened and approved by the GBP Quality Control Officer.

Seine net mesh size was increased from 3/16 inch to 1/4 inch after the first two pre-Project collections in 1993 from sampling sites E, G, and H (QAPP Appendix A, Section 4.6). This change in sampling gear resulted in significant declines in catch abundance of smaller forage fish without altering diversity of representative assemblages. Data collected from 1993 sampling efforts at these sites were not included in making quantitative spatial or temporal comparisons between sites unless otherwise noted. At sites C, D, I, and F, 1/8 inch mesh seines were used from 1992 through 1998. Since 1999, a 3/16 inch mesh bag seine has been used at these sites in place of the 1/8 inch mesh bag seine that was previously used by the USFWS.

As discussed earlier, biological sampling in Mud Slough was moved from Site I to Site I2, a new site about 0.5 km upstream with a larger, more permanent backwater area.

Results

Salt Slough (Site F)

Fish (Whole-Body)

Salt Slough is a principal wetland water supply channel from which drainwater has been removed by the GBP. Concentrations of selenium in Salt Slough fish composite samples declined during the first year of operation of the GBP but have stabilized since then at levels well below the concern threshold (Figures 2 and 3), with the exception of March 1998 when concentrations rose in the aftermath of storms that resulted in releases of drainwater into Salt Slough and in June 2001 when the selenium concentration (5.0 mg/kg dry weight)[5] in a single 1.8 gram logperch (Percina caprodes) exceeded the concern threshold for warmwater fish (4 mg/kg). The average of all composite samples of fish at this site during the 15-month period of October 2001 through December 2002 was 2.59 mg/kg (n=57), substantially below the warmwater fish concern threshold (4 mg/kg), significantly below the pre-Project average (6.74 mg/kg, n=77; $p<0.0001$), but not different from the average for the previous year (WY 2001: 2.60 mg/kg, n=51; p=0.89).

Tadpoles

Frog tadpoles (mainly bullfrog, Rana catesbeiana) have been collected only occasionally in the GBP area. Results suggest that in Salt Slough, selenium concentrations in tadpoles, as in fish and invertebrates, declined after implementation of the GBP (Figure 4). A composite sample of four bullfrog tadpoles collected in Salt Slough in August 1999 had about half the selenium concentration (2.6 mg/kg) of a single bullfrog tadpole collected in March 1993 (5.8 mg/kg). Selenium concentrations appeared to rise in the summer of 2000 (2.9 mg/kg in a

5 Calculated from wet weight using average percent moisture of 79.3%

composite sample of three bullfrog tadpoles in June 2000 (7.5 mg/kg in a composite sample of three tadpoles, and 2.3 mg/kg in a single, 19 g frog in August 2000), returned to lower levels in the summer of 2001 (3.8 mg/kg in a single, 0.4 g tadpole in June 2001; 2.5 mg/kg in a composite sample of 13 tadpoles in August 2001), but rose again in the summer of 2002 (5.2 mg/kg in a composite sample of 10 tadpoles in August 2002). The tadpole sample collected in November 2001 (2.9 mg/kg in a composite sample of 4 individuals) was just below the concern level (as diet). However, sample sizes are too small for drawing conclusions about year-to-year trends.

Invertebrates

During the 15-month period of October 2001 through December 2002, selenium concentrations in invertebrates collected from Salt Slough (Figure 5) remained within the range of concentrations associated with no known adverse effects (<3 mg/kg) on animals that eat invertebrates. The mean concentration of selenium in all invertebrate samples collected during this 15-month period (1.6 mg/kg, n=16) was significantly below (p<0.00001) the pre-Project mean (4.4 mg/kg, n=27), and significantly below (p=0.007) the WY 2001 mean (2.2 mg/kg, n=9).

Mud Slough 0.4 km above SLD Outfall (Site C)

Fish (Whole-Body)

During the 15-month period of October 2001 through December 2002, the average selenium concentration in fish just above the SLD (3.64 mg/kg, n=66) rose significantly from the previous year (WY 2001: 3.0 mg/kg, n=63, p=0.035) and was significantly above (p=0.003) the pre-Project average at this site (2.78 mg/kg, n=37; Figures 6 and 7). The warmwater fish concern threshold (4 mg/kg; see Table 1) was exceeded by the average selenium concentrations in inland silverside and/or red shiner composite samples in every sampling period from November 2001 through 2002, except June 2002. Elevated average selenium concentrations in some samples at this site may be due to the influence of individual fish swimming upstream from the more contaminated reach of Mud Slough below the discharge of the San Luis Drain.

Tadpoles

At site C, a sample of 16 bullfrog tadpoles (average mass 2.0 g per tadpole) was collected in August 2002. The selenium concentration in this sample (3.28 mg/kg) was in the middle of the range of concentrations in tadpole samples collected previously at this site (Figure 8), above the threshold of concern (3 mg/kg) for dietary effects on birds that may forage on tadpoles. No tadpoles were collected at this site prior to WY1999.

Invertebrates

In the sixth year of operation of the GBP, selenium concentrations in invertebrates at Site C declined even farther below the concern threshold than in previous years, (Figure 9). The average concentration in all invertebrate composite samples in 2002 was 1.34 mg/kg (n=18), significantly below (p=0.23) the average of the previous year (1.84 mg/kg, n=14), and significantly below (p=0.009) the pre-Project average (1.95 mg/kg, n=15).

Mud Slough 0.2 km below SLD Outfall (Site D)

Fish (Whole-Body)

During the 15-month period of October 2001 through December 2002, at site D, about 200 m below the SLD outfall, the average selenium concentration in small fish (6.19 mg/kg, n=57) decreased significantly (p=0.049) below the average for the previous year (WY 2001: 7.28 mg/kg, n=42), remaining significantly (p<0.0001) above the pre-Project mean (3.83 mg/kg, n=67; Figures 10 and 11). As in previous years, within Water Year 2002, selenium concentrations in fish exhibited significant (p=0.012) seasonal variation (November 2001-March 2002 average: 5.34 mg/kg, n=22; June-August 2002 average: 6.88 mg/kg, n=25). However, the summer increase was less pronounced than in recent previous years (for example, November 2000-March 2001 average: 3.7 mg/kg, n=11; June-August 2001 average: 8.6 mg/kg, n=31, p<0.00001). Though sampling efforts remained generally the same as in previous years, no samples of medium-sized fish were collected from Site D during the fifteen month study period (Figure 11).

Tadpoles

Tadpoles have only be collected occasionally in Mud Slough below the San Luis Drain outfall, and selenium concentrations have always been within the range that is of concern as diet for birds that prey on aquatic vertebrates (3-7 mg/kg). However, during the 15-month period of October 2001 through December 2002, a single 2.3-gram bullfrog tadpole collected in August 2002 at this site had a selenium concentration of 2.37 mg/kg (Figure 12), below the threshold of concern (Figure 12).

Invertebrates

Invertebrates have been relatively scarce at Site D throughout the history of the GBP monitoring program. From October 2001 through December 2002 only three samples of invertebrates (27 backswimmers, 3 red crayfish, and about 200 waterboatmen) could be collected at this site. Average selenium concentration in invertebrate samples (2.52 mg/kg, n=3) during the 15-month period of October 2001 through December 2002 did not change significantly (p=0.224 compared to the previous year (WY 2001: 4.43 mg/kg, n=8; Figure 13).

Mud Slough 1.5 km below SLD Outfall (Site I/I2)

Fish (Whole-Body)

At Site I2, average selenium concentration in fish (8.12 mg/kg, n=63) during the 15-month period from Oct 2001 through December 2002 did not change significantly (p=0.08) compared to the previous water year (WY 2001: 9.24 mg/kg, n=59; Figures 14 and 15). The comparison is confounded by the inclusion of an additional sampling event (Nov. 2002) in the most recent study period and by the inclusion of a single sampling event at the previous Site I in the WY 2001 data (the change of sampling site from Site I to Site I2 occurred in March of 2001; see Beckon et al. 2003). However, a more equal, calendar year comparison also shows no significant difference (p=0.18) between the average selenium concentration in fish at Site I2 (no Site I data included) in 2002 (8.31 mg/kg, n=52) compared to 2001 (9.17 mg/kg, n=64). As at Site D and at Site I in previous years, selenium concentration exhibited a seasonal increase (p=0.013) from early spring (March average 7.55, n=16) to late summer (August average 10.3, n=16). In August 2002 at Site I2, selenium concentrations in all fish samples were elevated well

into the toxicity zone for fish as diet for piscivorous birds (>7 mg/kg). All but one sample was above the toxicity threshold for effects on warmwater fish themselves (>9 mg/kg).

As in the previous year, greater bioaccumulation of selenium appeared to occur at I2 compared to Site D. The 15-month (Oct 2001 through Dec 2002) average selenium concentration in all fish samples at Site I2 (8.12 mg/kg) was significantly higher (p=0.004) than the 15-month average at Site D (6.19 mg/kg). This may in part be a real effect due to more efficient bioaccumulation in the backwater conditions at Site I2. However, because Site D is much closer than Site I2 to the Drain discharge point, it is likely that a composite samples of fish and invertebrates collected at Site D include substantial numbers of individuals that have moved downstream from the cleaner reach of Mud Slough above the outfall of the Drain, thereby diluting the average selenium concentrations in the biota at Site D.

Tadpoles

Tadpoles have not been collected at this site.

Invertebrates

Average selenium concentration in all invertebrates collected at Site I2 during the 15-month period of October 2001 through December 2002 (4.51 mg/kg, n=9) was not significantly different (p=0.36) from the previous water year (WY 2001: 5.06 mg/kg, n=13; Figure 16). However, it was significantly higher (p=0.01) than the pre-Project average at Site I (2.65 mg/kg, n=8). Seven of the eight invertebrate samples collected at this site had selenium concentrations above the threshold of concern for birds that would forage on these invertebrates (3 mg/kg). A single sample of zooplankton (a mixture of thousands of microscopic invertebrates, mainly Daphnia) collected at this site in November 2002 had a selenium concentration of 4.82 mg/kg, well above the selenium concentration in the single sample of more than 200 waterboatmen collected at the same time at the same site (2.16 mg/kg). This suggests that microscopic invertebrates may represent an even greater risk to the aquatic and aquatic-dependent food webs than the larger water-column invertebrates (waterboatmen and backswimmers) that have been the focus of water-column invertebrate monitoring in this project.

Lower Mud Slough and San Joaquin River Sites

Mud Slough at Highway 140 (Site E)

Site E is located in lower Mud Slough downstream from Sites D and I2 but upstream from the confluence of Mud Slough with the San Joaquin River. This site represents the lower reach of the Slough that is affected by the operation of the Project. At this point along Mud Slough, within the flood plain of the San Joaquin River, flows are slower and more spread out, and flood waters of the San Joaquin River periodically back up into slough, providing some flushing. Selenium in whole body fish and invertebrate samples collected at this site in WY 1999, 2000 and 2001 and the fifteen month study period confirm the trend of increasing concentrations that is evident at Sites D, I, and I2.

Fish (Whole-Body)

The concentration of selenium in composite samples of whole-body mosquitofish (*Gambusia affinis*) collected during the fifteen month study period ranged from 8.8 to 14.8 mg/kg (dry weight), with six of seven samples exceeding the toxicity threshold (9 mg/kg dry

weight) in June, August, and December 2002 (Figure 17). The average selenium concentration of all fourteen samples of whole-body fish collected from this site during the fifteen month study period was 11.6 mg/kg.

The average concentration of selenium in six composite samples of wholebody mosquitofish collected during WY 2002 was 11.04 mg/kg (dry weight). This was not significantly different from samples collected during WY 2001 (9.22 mg/kg dry weight, n=12, p=0.123), but is significantly higher than the average concentration of samples collected during WY 2000 (6.77 mg/kg dry weight, n=12, p=0.002) and the average pre-project concentration of 2.5 mg/kg dry weight (n=12, p<0.000).

<u>Invertebrates</u>

Crayfish were not difficult to catch at this site during the fifteen month study period. Six composite samples of crayfish collected at this site during November 2001 and March 2002 had selenium concentrations within the concern range (3 - 7 mg/kg dry weight) for invertebrates (Figure 18). Two composite samples collected during August and December 2002 exceeded the toxicity threshold of 9 mg/kg dry weight.

The average concentration of selenium in all six crayfish samples collected during WY 2002 was 5.96 mg/kg (dry weight). This concentration was the same as the previous two water years, but significantly higher than the average selenium concentration in crayfish caught at this site before 1996 (μ=1.72 mg/kg dry weight, n=15, p=0.009).

The concentration of selenium in waterboatmen collected from this site during March 2002 was 4.1 mg/kg (dry weight), above the 3 mg/kg (dry weight) concern threshold. In prior water years, annual samples of waterboatmen were below the 3 mg/kg concern threshold.

San Joaquin River at Fremont Ford (Site G)

Site G is located at Fremont Ford on the San Joaquin River upstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River that no longer receives agricultural drainwater from the Grassland Drainage Area as a result of the GBP.

<u>Fish (Whole-Body)</u>

Similar to the first five years of GBP operation, selenium concentrations in composite samples of fish collected from this site continued to reflect removal of selenium-laden drain water. Selenium concentrations in composite samples of whole-body mosquitofish collected during the fifteen month study period ranged from 1.17 to 1.89 mg/kg (dry weight), remaining well below the concern threshold (4 mg/kg dry weight) for warmwater fish (Figure 19). Average selenium concentration for all mosquitofish collected in the fifteen month study period was 1.62 mg/kg (dry weight) (n=15).

The average concentration of selenium in twelve composite samples of mosquitofish collected during WY 2002 was 1.64 mg/kg (dry weight). This was less than the previous year (WY 2001, μ=1.99, n=12, p=0.001), and significantly less than the pre-project average concentration of selenium of 4.79 mg/kg (dry weight) measured in fifteen samples. Selenium concentrations in whole-body mosquitofish have consistently been within or below the Concern range (4 - 9 mg/kg dry weight) since the GBP began September 1996.

Invertebrates

Selenium concentrations in all invertebrates collected from this site during the fifteen month study period were less than all previous years since project operations began (Figure 20). The average concentration of selenium in nine composite samples of crayfish collected during the fifteen month study period was 1.21 mg/kg (dry weight). The selenium concentrations ranged from 0.92 to 2.36 mg/kg (dry weight), remaining below the 3 mg/kg (dry weight) threshold of concern for invertebrates as prey items.

The average concentration of selenium in seven composite samples of red crayfish caught during WY 2002 was 1.02 mg/kg (dry weight). This was not significantly different than the average concentration of selenium in nine crayfish samples caught at this site during WY 2001 (μ=1.48 mg/kg, p=0.047). The WY 2002 average selenium concentration was significantly greater than that for WY 2000 (μ=0.42, n=8, p=0.000). However, the average selenium concentration of all samples collected during WY 2002 was significantly less than the pre-project level of 3.5 mg/kg dry weight (n=9, p=0.001).

Similar to crayfish, the concentration of selenium in all samples of waterboatmen collected from this site during WY 2002 continued to be well below the 3 mg/kg (dry weight) concern threshold, with an average selenium concentration of 1.4 mg/kg (dry weight); All samples of waterboatmen have consistently remained below the concern threshold during all water years since Project operations began September 1996.

San Joaquin River Below Mud Slough (Site H)

Site H is located at Hills Ferry on the San Joaquin River about two miles downstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River most strongly influenced by agricultural drain water discharged by the GBP. One of the environmental commitments of the GBP is that it will not worsen water quality in the San Joaquin River. For practical reasons of year-round accessibility, the site was located just upstream of the Merced River confluence; Merced River waters have relatively low concentrations of selenium. It is possible that some of the fish and invertebrates collected at Site H have moved into this area after foraging within the Merced River and other less contaminated reaches of the San Joaquin River.

Additionally, seasonally high flows in the Merced River can enter the San Joaquin River upstream of Site H, temporarily diluting the load of contaminants there. Due to these confounding influences on selenium body burdens, selenium concentrations in fish and invertebrate tissues collected at this site may not be well correlated with water concentrations of selenium at this site.

Fish (Whole-Body)

Selenium concentrations in fifteen composite samples of whole-body mosquitofish collected during March and December 2002 were above the 4 mg/kg (dry weight) concern threshold for warmwater fish (Figure 21). The average of all samples collected during the fifteen month study period (μ = 4.12 mg/kg)

The average concentration of selenium in twelve composite samples of wholebody mosquitofish collected form this site during WY 2002 was 3.82 mg/kg (dry weight). This was not significantly different than the previous water year (μ=3.75 mg/kg, n=9, p=0.749). Despite

this, selenium concentrations in composite whole-body fish samples throughout the five years of GBP operation have generally remained below the 4 mg/kg (dry weight) concern threshold and are not significantly different from selenium concentrations in fish collected before the GBP began in 1996 (μ=3.78, n=21, p=0.924).

Invertebrates

Selenium concentrations in nine composite samples of red crayfish collected from this site during the fifteen month study period ranged from 1.31 mg/kg to 5.08 mg/kg (dry weight), with an average of 2.69 mg/kg, which is slightly below the 3 mg/kg (dry weight) concern threshold associated with known adverse effects on higher order consumers (Figure 22). The concentration of selenium in one composite sample of water boatmen, collected March 2002, was 2.73 mg/kg (dry weight), similar to WY 2001.

The average concentration of selenium in eight composite samples of red crayfish caught during WY 2002 was 2.40 mg/kg (dry weight). This average was not significantly different than the previous water year (μ=3.34, n=3, p=0.053) or from the concentration of selenium measured in nine samples collected before the project began in 1996 (μ=2.08 mg/kg, p=0.541).

Fish Communities Assessment

Fish communities assessments are conducted to describe fish assemblages based on species richness, abundance and community structure. Fish populations were sampled in Mud Slough at Highway 140 (Site E), San Joaquin River at Fremont Ford (Site G), and San Joaquin River below Mud Slough (Site H). Fish assemblages from these sites were compared both spatially and temporally to see if conditions for fish species in the San Joaquin River improved and conditions in Mud Slough degraded. We sampled in August and November 1993, March, June, and August/September of the years 1996 – 1999, November 2001, and December 2002. We did not sample during November 2000. As the Grassland Bypass Project began operation in September 1996, this sampling schedule provided a before-and-after picture of the fish communities at these sites. Only data collected with standardized sampling methodologies and effort were analyzed.

Table 3 is a compilation of the 34 fish species, represented by 20,104 individuals, that have been collected at these sites during five pre-project and eighteen post-Project sampling events. Ten species of native fish were caught, representing only three percent of the catch by number (n = 512).

Only four native species were caught during November 2001 and December 2002 at the three sites: Pacific staghorn sculpin (Leptocottus armatus, n= 74), Sacramento sucker (n=4), Sacramento splittail (n=3), and Sacramento blackfish (n=2). The fish screen at Site H prevents salmon from moving upstream to the sampling sites for this project.

Pacific staghorn sculpin were the most abundant native fish throughout the study. The most common non-native fish are mosquitofish, inland silversides, fathead minnow, and carp.

No time trends are apparent in fish species assemblages during the period 1993 to 2002 at Sites E, G, and H (Figures 23-25). Omnivores were dominant at Site E and invertivores were dominant at Sites G and H in the San Joaquin River. No time trend is evident in total anomalies for the various groups of fishes at each site (Figure 26).

During September and October 1997, about one year after the reopening of the SLD, Saiki (1998) sampled fish at 13 sites in the Grassland area. These sites correspond to locations he had surveyed more than a decade earlier (Saiki 1986). Some of his sample sites were the same as, or close to, GBP monitoring sites, but others were located in areas not monitored by the GBP. The SLD was the only site in the area that lacked bluegill and goldfish, and overall, fewer species of fish were found in the SLD than at any other site. However, Saiki did not find any significant difference in community structure related to the proportion of drainwater present. To explain this, he noted that all waterways in the area are overwhelmingly dominated by introduced species having broad environmental tolerances. Saiki's findings are consistent with those of the GBP biological monitoring program.

After 6 years of Project operation, no clear pattern of temporal or geographic variation in fish community structure attributable to the Project has emerged. However, current methods of assessing fish species assemblages may lack the power to detect all but the most pronounced alterations in community structure.

Assessment of Risk to Public Health from Consumption of Fish

During the first five years of GBP operation, samples of carp muscle tissue collected from Site E were below the 2 mg/kg health screening level for selenium, except for samples collected in September 1997 and August 1998. The concentration of selenium in eleven composite samples of carp caught between March 1999 and August 2001 ranged from 0.84 – 1.68 mg/kg (wet weight). These concentrations are comparable to those in four composite samples caught before the GBP began (0.61 – 1.25 mg/kg wet weight). During the fifteen month study period, the average concentration of selenium in samples of carp collected in November 2001 and August 2002 exceeded the 2 mg/kg health screening level. The average concentration of selenium in carp tissue collected in March, June, and December 2002 did not exceed the health screening level (Figure 27).

The concentration of selenium in carp collected at Site E during the fifteen month study period ranged from 0.51 to 2.73 mg/kg (wet weight, n=15). Four composite samples collected in November 2001 and August 2002 exceeded the 2 mg/kg (wet weight) selenium health screening level (Figure 27).

The average concentration of selenium in twelve carp muscle tissue sampled during the Water Year 2002 was 1.67 mg/kg (wet weight). This average was significantly different than the average from the previous water year (μ=1.21 mg/kg, n=9, p=0.050) and from the average of eleven samples collected prior to the beginning of the project in 1996 (μ=0.74 mg/kg, p=0.001).

The concentration of selenium concentrations in carp fillets collected at Sites G (μ=0.51 mg/kg wet wt, n=15) and H (μ=0.74 mg/kg wet weight, n=15) on the San Joaquin River have remained consistently below the 2 mg/kg health screening level throughout all five years of GBP operations (Figures 28 and 29).

Selenium in Plants

Composite samples of plant material that provides preferred forage for waterfowl (seed heads) have been collected in late summer for several years, but funding has only been adequate to analyze some of these materials for selenium in the last two years (Figure 30). In WY 2002,

the highest selenium concentrations found in water-side plants were from samples collected along Mud Slough downstream of the San Luis Drain (Sites D and I2). All samples were well below the threshold of concern for reproductive effects on waterfowl due to dietary exposure (3 mg/kg) except a composite sample of swamp timothy seed heads (3.5 mg/kg) collected from the banks of Mud Slough below the San Luis Drain outfall (Site D). The selenium concentration in samples of bullrush sedge, cattail, and swamp timothy collected at sites C, D, F and I2 in August 2002 were all below the analytical reporting limit of 0.20 mg/kg, dry weight. These data suggest that birds in this area are generally at greater risk due to eating invertebrates and fish than from eating plants.

The concentrations of selenium in knotgrass (Paspalum disthum) seed heads collected by CDFG at Sites E, G, and H were below the 3 mg/kg (dry weight) threshold of concern. The average concentration of selenium in three composite samples of seeds collected during August 2002 at Site E was 0.55 mg/kg dry weight. This average is significantly different from the average of seed samples collected before the GBP began in 1996 (μ=0.30, n=3, p=0.031).

The average concentration of selenium in seed collected at Site G was 0.03 mg/kg dry weight. This average was significantly less than the average selenium concentration in seed collected before the GBP began (μ=0.20 mg/kg dry weight, p=0.000).

The average concentration of selenium in seed collected at Site H was 0.15 mg/kg dry weight. This average was not significantly different than the average selenium concentration in seed collected before the GBP began (μ=0.23 mg/kg dry weight, p=0.293).

Selenium in Bird Eggs

In 2002, a single egg was randomly collected and analyzed from each of 13 bird nests in the Grassland area, and, for comparison, from one mallard duck nest on the San Joaquin River National Wildlife Refuge (Figure 31). Species sampled included killdeer, American avocet, wood duck, barn swallow, cliff swallow, and starling. The selenium concentrations in all eggs collected in 2002 were within the "no effect" range of concentrations (<6 mg/kg). Selenium concentrations in eggs analyzed from the Mud Slough area (geometric mean 2.38 mg/kg, n=10) were not significantly different (p=0.56, t-test performed on log-transformed concentrations) from those analyzed from the Salt Slough area (geometric mean 2.14 mg/kg, n=4) in 2002.

Aquatic Hazard Assessment of Selenium

To provide an estimate of ecosystem-level effects of selenium, Lemly (1995, 1996) developed an aquatic hazard assessment procedure that sums the effects of selenium on various ecosystem components to yield a single characterization of overall hazard to aquatic life. Lemly's procedure applied to Mud Slough downstream of the SLD outfall indicated that the hazard to aquatic life in the affected portion of Mud Slough continued to be "high" in WY 2002 (Table 3).

In the Salt Slough area, the Lemly index rose from "low" in WY 2000 to "moderate" in WY 2001 and back to low in WY 2002 (Table 3). Because the Lemly index is based on maximum concentrations, it is highly sensitive to data "outliers". A Lemly index was not determined for San Joaquin River sites due to lack of sufficient sample of invertebrates and because bird eggs, one component of the index, were not sampled there.

Boron in Plants

Samples of seed heads from plants (knotgrass, smartweed, swamp timothy, bullrush sedge) collected in August 2002 from Sites C, D, E, 12, F, G, and H were analyzed for boron.

At Site C, one of two samples (12.5, 47.5) exceeded the threshold of concern for boron in plants as diet (30 mg/kg, Table 2). One of three samples collected at Sites D and 12 were above the threshold of concern (Site D: 13.7, 64.2 mg/kg ; Site 12: 28.9). At Site E all samples exceeded the threshold of concern (74.5, 119, and 73.3 mg/kg). At Site F, the single sample analyzed was slightly above (30.6 mg/kg) the threshold of concern.

The concentration of boron in knotgrass seedheads (Paspalum distichum) collected at Site G on the San Joaquin River was 16.1 mg/kg (n=3), below the threshold of 30 mg/kg. The concentration of boron in knotgrass seedheads collected at Site H was 44.4 mg/kg which is above the threshold of concern.

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Table 1. Recommended Ecological Risk Guidelines for Selenium Concentrations.

Medium	Effects on	Units	No Effect	Concern	Toxicity
Water (total recoverable selenium)	fish and bird reproduction	µg/L	< 2	2 -- 5	> 5
Sediment	fish and bird reproduction	mg/kg (dry weight)	< 2	2 -- 4	> 4
Invertebrates (as diet)	bird reproduction	mg/kg (dry weight)	< 3	3 -- 7	> 7
Warmwater Fish (whole body)	fish growth/condition/survival	mg/kg (dry weight)	< 4	4 -- 9	> 9
Avian egg	egg hatchability (via foodchain)	mg/kg (dry weight)	< 6	6 -- 10	> 10
Vegetation (as diet)	bird reproduction	mg/kg (dry weight)	< 3	3 -- 7	> 7

Notes

1/ These guidelines, except those for avian eggs, are intended to be population based Thus, trends in means over time should be evaluated Guidelines for avian eggs are based on individual level response thresholds (e g , Heinz, 1996, Skorupa, 1998)

2/ A tiered approach is suggested with whole body fish being the most meaningful in assessment of ecological risk in a flowing system.

3/ The warmwater fish (whole body) concern threshold is based on adverse effects on the survival of juvenile bluegill sunfish experimentally fed selenium enriched diets for 90 days (Cleveland et al., 1993) It is the geometric mean of the "no observable effect level" and the "lowest observable effect level "

4/ The toxicity threshold for warmwater fish (whole body) is the concentration at which 10% of juvenile fish are killed (DeForest et al., 1999)

5/ The guidelines for vegetation and invertebrates are based on dietary effects on reproduction in chickens, quail and ducks (Wilber, 1980, Martin, 1988, Heinz, 1996)

6/ If invertebrate selenium concentrations exceed 6 mg/kg then avian eggs should be monitored (Heinz et al , 1989, Stanley et al , 1996).

Table 2. Recommended Ecological Risk Guidelines for Boron Concentrations.

Medium	Effects on	Units	No Effect	Concern	Toxicity
Water	fish (catfish and trout embryos)	mg/L	< 5	5 -- 25	> 25
Water	invertebrates (*Daphnia*)	mg/L	< 6	6 -- 13	> 13
Water	vegetation (crops and aquatic plants)	mg/L	< 0.5	0.5 -- 10	> 10
Waterfowl diet	duckling growth	mg/kg (dry weight)		> 30	
Waterfowl egg	embryo mortality	mg/kg (dry weight)	<1	> 10	>30

Notes

1/ Water guidelines for invertebrates are based on the "no observed adverse effects level" and "lowest observed adverse effects level" for *Daphnia magna* (Lewis and Valentine 1981, Gersich 1984).

2/ Waterfowl diet guidelines are based on mallard ducks (Smith and Anders 1989)

3/ The waterfowl egg no effect level is based on poultry data from Romanoff and Romanoff (1949) and San Joaquin Valley field data for reference sites (R L. Hothem and Welsh; J P Skorupa et al.).

4/ The waterfowl egg concern and toxicity thresholds are based on Smith and Anders (1989), Stanley et al (1996), and the "order-of-magnitude rule of thumb" (toxicity at about 10 times background concentrations)

5/ The US Environmental Protection Agency's suggested no adverse response level for drinking water is 0 6 mg/L.

Table 3. Fishes collected from Grassland Bypass Project Stations E, G, and H in decreasing order of numerical abundance. August 1993 - December 2002

Species Common name, *Scientific name*	Number Collected	Origin	Trophic Classification	Tolerance to environmental degradation	native
Mosquitofish, *Gambusia affinis*	14,368	Introduced	I	T	0
Inland silverside, *Menidia beryllina*	3,370	Introduced	I	M	0
Carp, *Cyprinus carpio*	2,505	Introduced	O	T	0
Fathead minnow, *Pimephales promelas*	2,184	Introduced	O	T	0
Red shiner, *Cyprinella lutrensis*	1,318	Introduced	O	T	0
White catfish, *Ameiurus catus*	1,298	Introduced	I/P	T	0
Bluegill, *Lepomis macrochirus*	866	Introduced	I	T	0
Threadfin shad, *Dorosama petenese*	513	Introduced	I	M	0
Largemouth bass, *Micropterus salmoides*	454	Introduced	P	T	0
Goldfish, *Carassius auratus*	404	Introduced	O	T	0
Green sunfish, *Lepomis cyanellus*	382	Introduced	I/P	T	0
Redear sunfish, *Lepomis microlophus*	279	Introduced	I	M	0
Channel catfish, *Ictalurus punctatus*	254	Introduced	I/P	M	0
Sacramento blackfish, *Orthodon microlepidotus*	219	Native	O	T	219
Warmouth, *Lepomis gulosus*	215	Introduced	I	M	0
Splittail, *Pogonichthys macrolepidotus*	111	Native	O	M	111
Bigscale logperch, *Percina macrolepida*	101	Introduced	I	T	0
Pacific staghorn sculpin, *Leptocottus armatus*	74	Native	I/P	M	74
Black crappie, *Pomoxis nigromaculatus*	57	Introduced	I/P	M	0
Brown bullhead, *Ameiurus nebulosus*	40	Introduced	I/P	T	0
Smallmouth bass, *Micropterus* dolomieui	37	Introduced	I/P	M	0
Spotted bass, *Micropterus punctulatus*	37	Introduced	P	M	0
Striped bass, *Morone saxatilis*	30	Introduced	P	M	0
Sacramento sucker, *Catostomus occidentalis*	29	Native	O	M	29
Prickly sculpin, *Cottus asper*	28	Native	I	M	28
Chinook salmon, *Oncorhynchus tshawytscha*	26	Native	I	I	26
Sacramento pikeminnow, *Ptychocheilus* grandis	21	Native	I/P	M	21
Black bullhead, *Ameiurus melas*	14	Introduced	I/P	T	0
American shad, *Alosa sapidissima*	13	Introduced	I	M	0
Golden Shiner, *Notemigonus crysoleucas*	11	Introduced	I	M	0
Bullfrog, *Rana catesbeiana*	10	Introduced	O	T	0
White crappie, *Pomoxis annularis*	10	Introduced	I/P	T	0
Red crayfish, *Procambarus clarkii (Scapulicambar*	6	Introduced	O	T	0
Hitch, *Lavinia exilicauda*	4	Native	O	M	4
Tule perch, *Hysteocarpus traski*	4	Native	I	I	4
Pumpkinseed, *Lepomis gabbosus linaeas*	2	Introduced	I	M	0
Riffle sculpin, *Cottus gulosus*	1	Native	I	M	1
Total	29,295				517
Data Source: California Department of Fish and Game					2%

Notes:

Trophic Classification: O - omnivore
I - invertivore
P - piscivore
I/P - invertivore/piscivore

Tolerance to environmental degradation: I - intolerant
M - moderately tolerant
T - tolerant

Table 4. Aquatic Hazard Assessment of Selenium in Mud and Salt Slough

		BEFORE PROJECT 1995 - Sept. 1996			GRASSLAND BYPASS PROJE WY1997			WY1998			WY1999			
	Units	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration	Lemly Aquatic hazard	Hazard Scale	Maximum Selenium concentration
Mud Slough below Drain outfall														
Water	µg/L	19	high	5	80	high	5	104	high	5	51	high	5	66
Sediment	µg/g	0.4	none	1	0.8	none	1	2.0	low	3	4.8	high	5	4.4
Invertebrates	µg/g	1.6	none	1	3.3	low	3	11.0	high	5	7.0	high	5	15.3
Fish eggs	µg/g	14.2	moderate	4	56.1	high	5	34.2	high	5	39.6	high	5	46.5
Bird eggs	µg/g	3.1	minimal	2	4.4	minimal	2	6.6	low	3	10.0	low	3	5.1
TOTAL HAZARD SCORE			**Moderate**	**13**		**High**	**16**		**High**	**21**		**High**	**23**	
Salt Slough														
Water	µg/L	38	high	5	3	moderate	4	5	high	5	2	minimal	2	2
Sediment	µg/g	0.8	none	1	0.9	none	1	2.1	low	3	0.9	none	1	0.7
Invertebrates	µg/g	4.7	moderate	4	2.6	minimal	2	3.2	low	3	2.8	minimal	2	2.7
Fish eggs	µg/g	28.1	high	5	17.8	moderate	4	12.9	moderate	4	11.2	moderate	4	14.5
Bird eggs	µg/g	5.2	low	3	3.6	minimal	2	3.7	minimal	2	2.7	none	1	4.9
TOTAL HAZARD SCORE			**High**	**18**		**Moderate**	**13**		**High**	**17**		**Low**	**10**	

Hazard Scale:

5	high
4	moderate
3	low
2	minimal
1	none

TOTAL HAZARD SCORE

16 - 25	**High**
12 - 15	**Moderate**
9 - 11	**Low**
6 - 8	**Minimal**
0 - 5	**None**

Notes: Table prepared by US Fish and Wildlife Service, Sacramento.
(*) October 1, 2001 - December 31, 2002.

Table 5. Maximum contaminant concentration data used for the Lemly Index (Table 4) for the period October 1, 2001 to December 31, 2002.

Mud Slough (San Luis Drain, Sites D, I, and I2)

Media	Sample Date	Location	Value	Sample Type	Sample Size	Data Source
Water	26-Apr-01	Site D	51 µg/L	weekly grab		CVRWQCB
Sediment	14-Nov-00	Site I	3.5 µg/g	0 - 3 cm		USBR
Invertebrates	21-Aug-01	Site I2	7.1 µg/g	waterboatmen	n=ca 200	US FWS I2B01AUG19
Fish eggs (*)	21-Aug-01	Site I2	16.6 µg/g whole- body Se x 3.3 = 54 8 µg/g in eggs	mosquitofish wholebody	n=25	US FWS I2B01AUG21
Bird eggs	25-Apr-01	SLD	7 µg/g	black phoebe	n=1	US WS SLD01APR02

(*) fish egg selenium = fish wholebody selenium x 3.3

Salt Slough (Site F)

Media	Sample Date	Location	Value	Sample Type	Sample Size	Data Source
Water	14-Mar-01	Site F	2 µg/L	weekly grab sample		CVRWQCB
Sediment	14-Mar-01	Site F	0.8 µg/g	whole core		USBR
Invertebrates	21-Mar-01	Site F	2.7 µg/g	Red crayfish	n=6	US FWS F01MAR07
Fish eggs (*)	21-Mar-01	Site F	3.8 µg/g whole- body Se x 3.3 = 12.5 µg/g in eggs	logperch	n=1	US FWS F01MAR06
Bird eggs	8-May-01	Site F	4 µg/g	black-necked stilt	n=1	US FWS SL01MAY01

(*) fish egg selenium = fish wholebody selenium x 3.3

Figure 1. Grassland Bypass Project biota monitoring sites

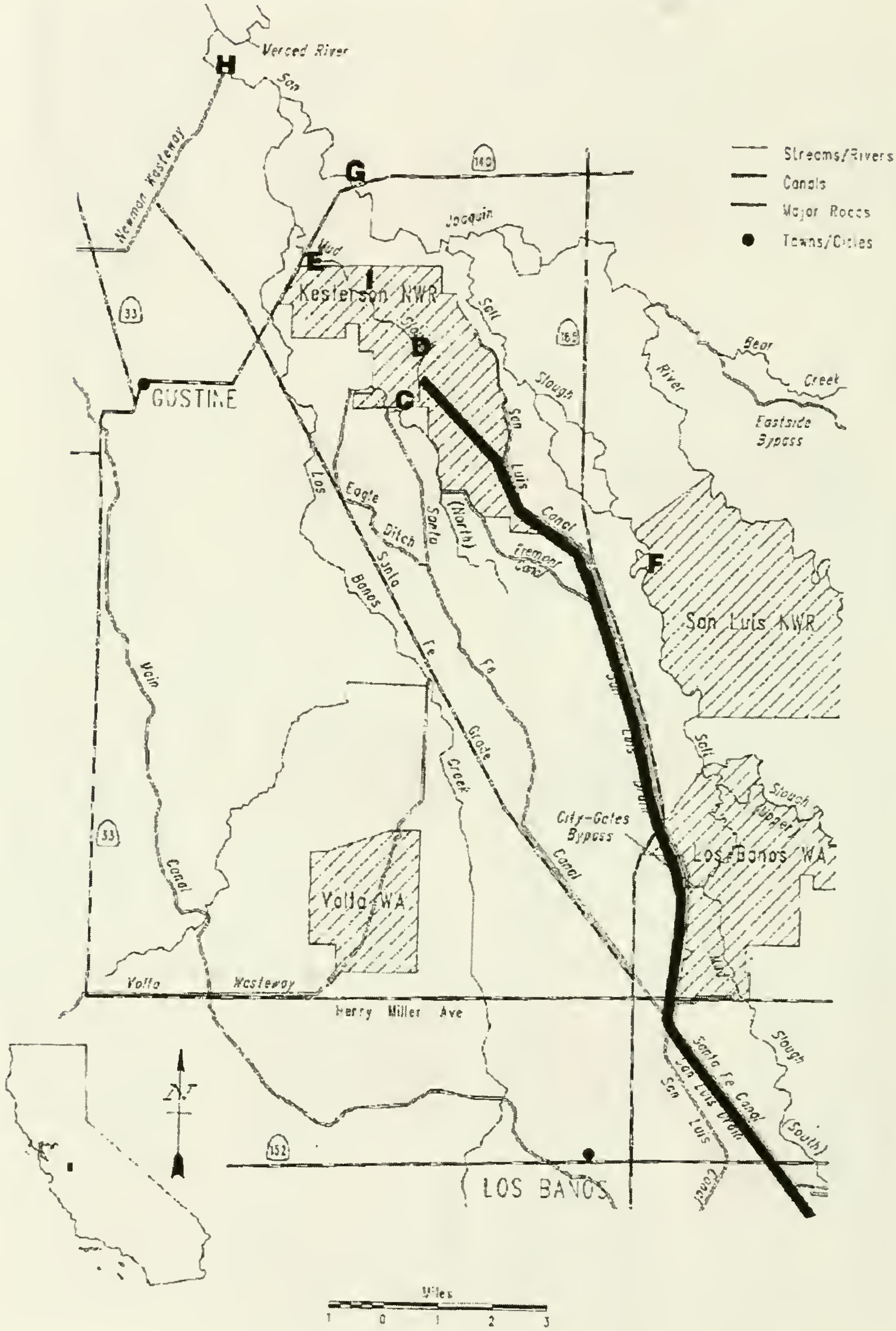


Figure 2. Selenium in small fish in Salt Slough (Site F). Each bar represents an average of composite samples.

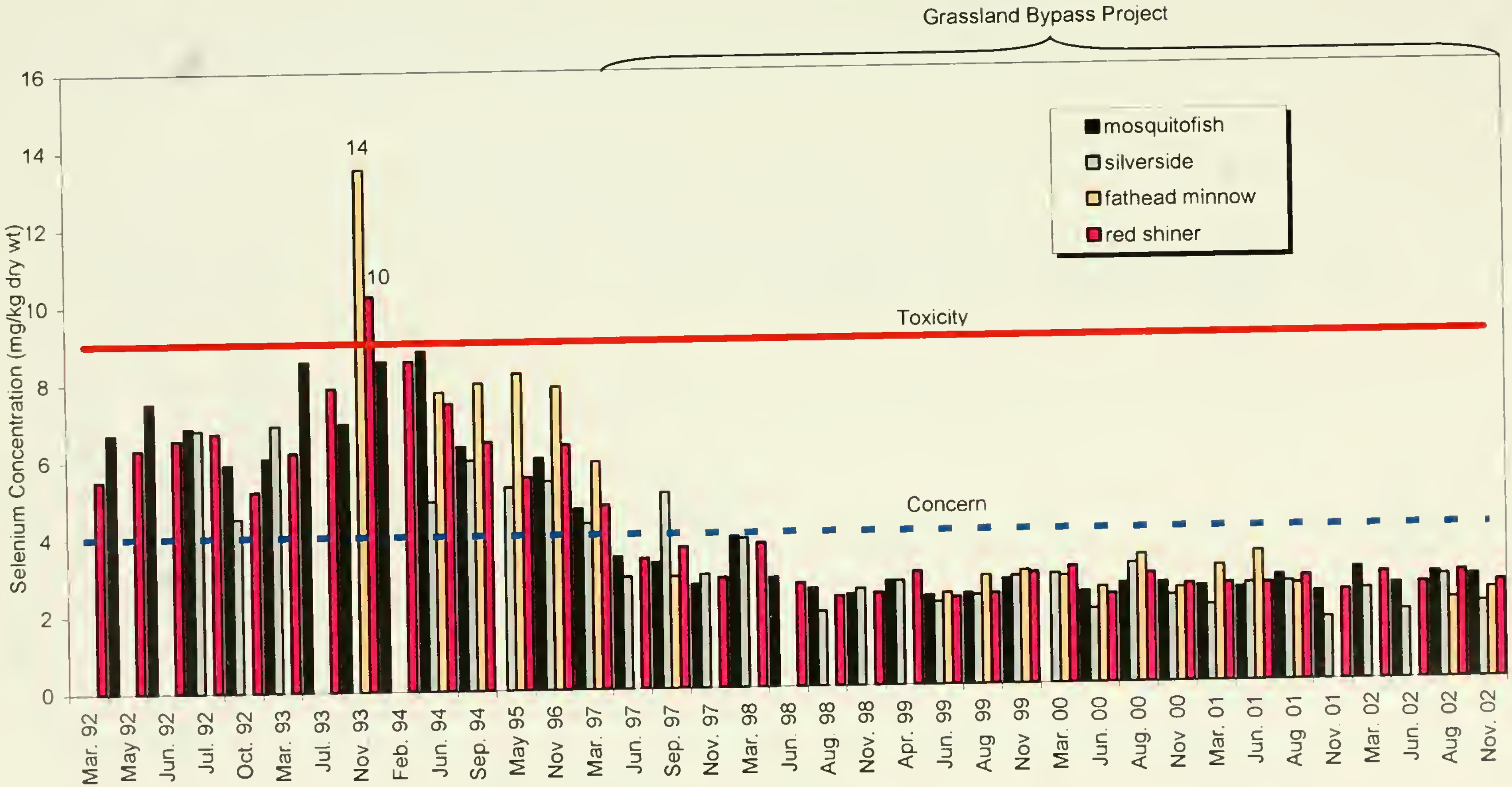


Figure 3. Selenium in medium-size fish in Salt Slough (Site F).

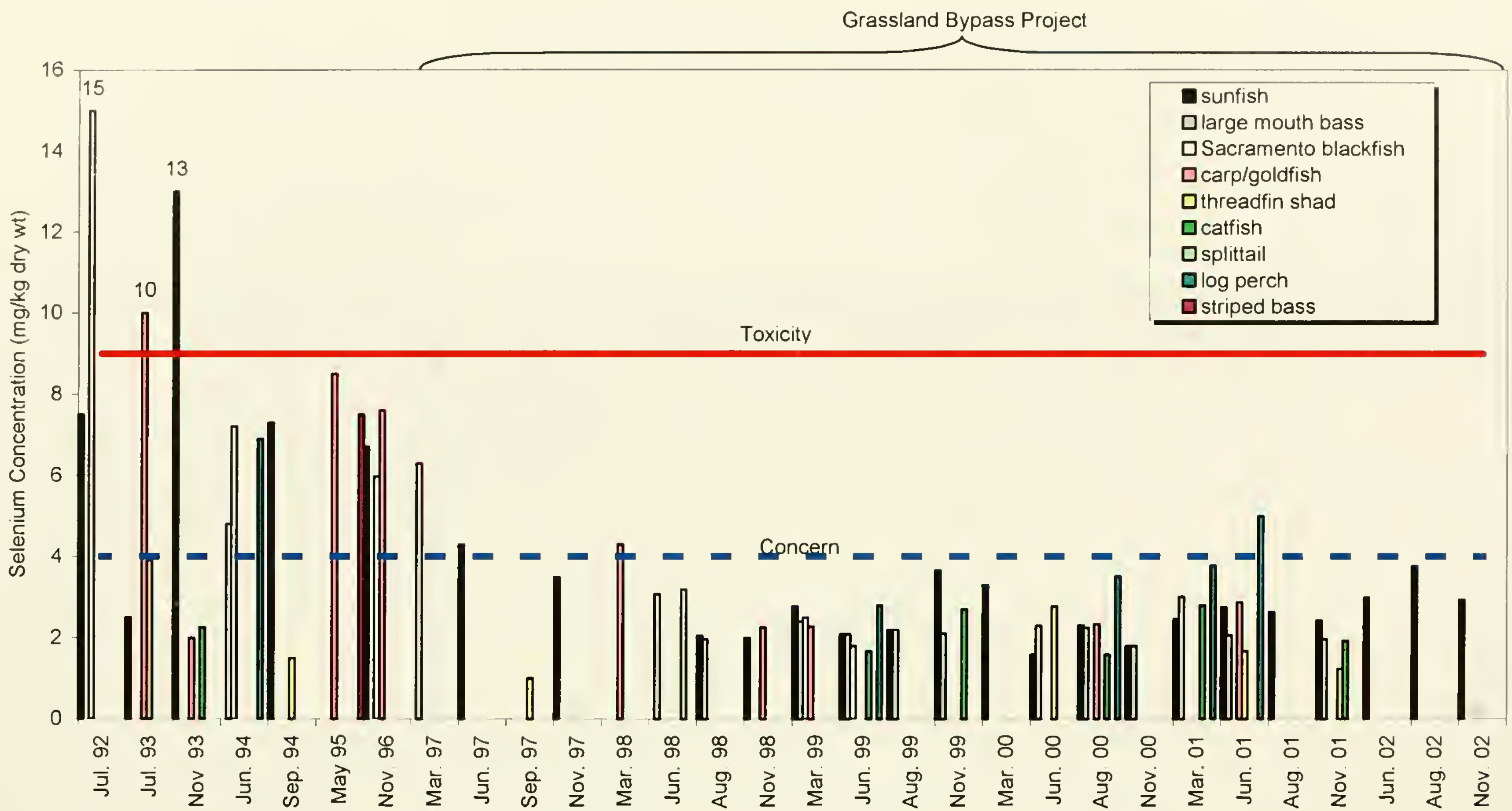


Figure 4. Selenium in bullfrog tadpoles in Salt Slough (Site F).

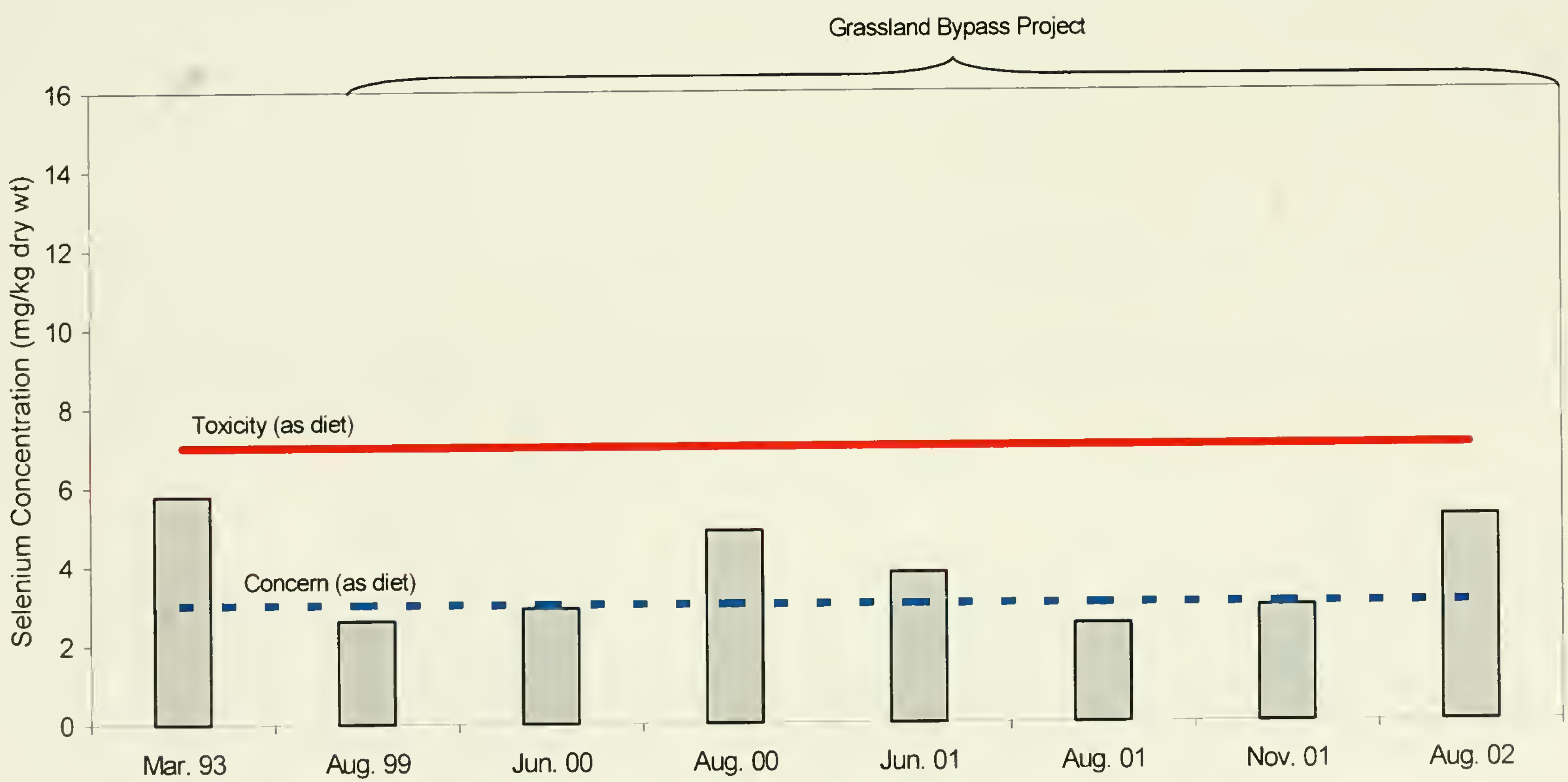


Figure 5. Selenium in invertebrates in Salt Slough (Site F).

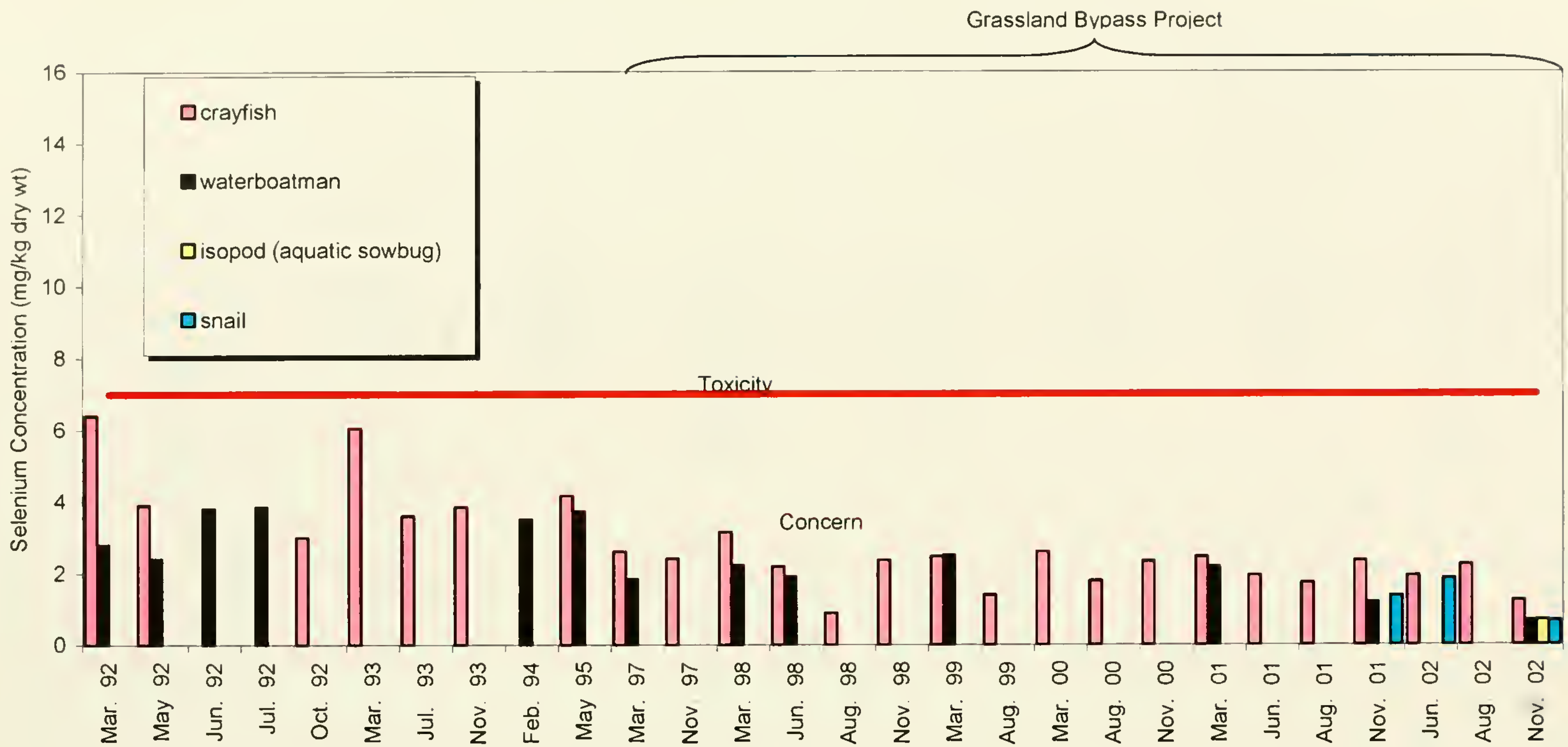


Figure 6. Selenium in small fish in Mud Slough above the San Luis Drain discharge (Site C).

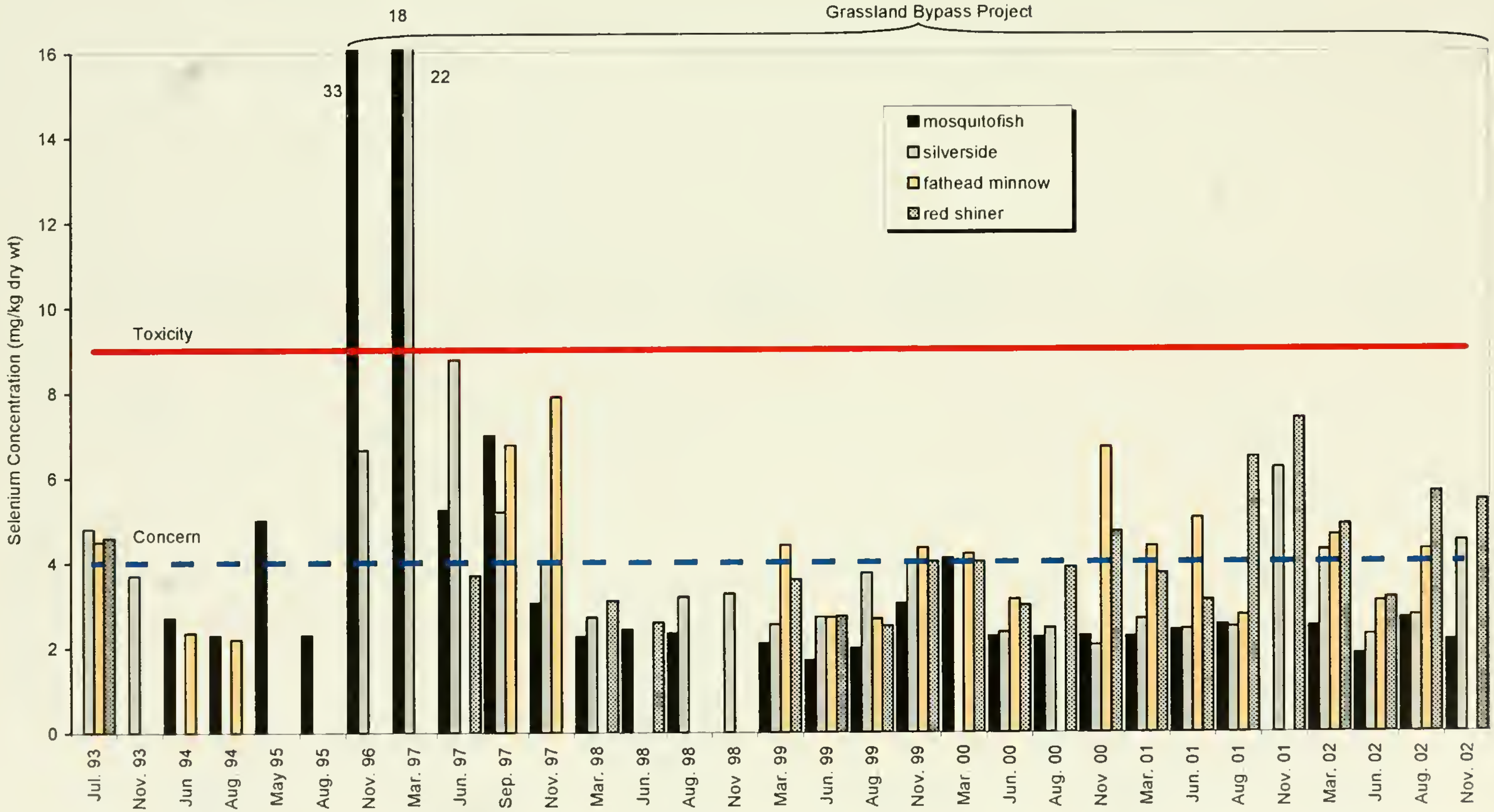


Figure 7. Selenium in medium-size fish in Mud Slough above the San Luis Drain discharge (Site C).

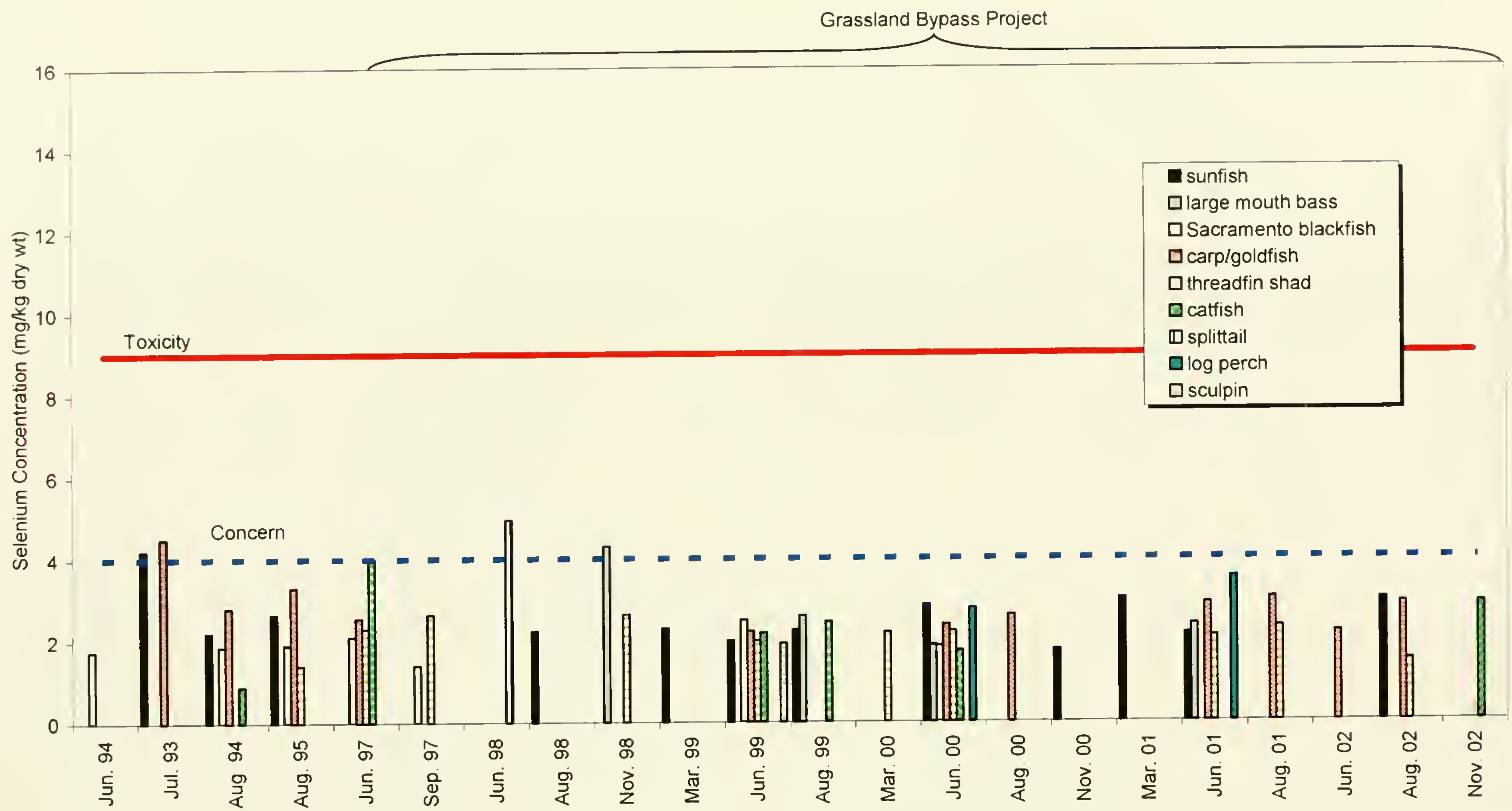


Figure 8. Selenium in bullfrog tadpoles in Mud Slough above the San Luis Drain discharge (Site C).

Figure 9. Selenium in invertebrates in Mud Slough above the San Luis Drain discharge (Site C).

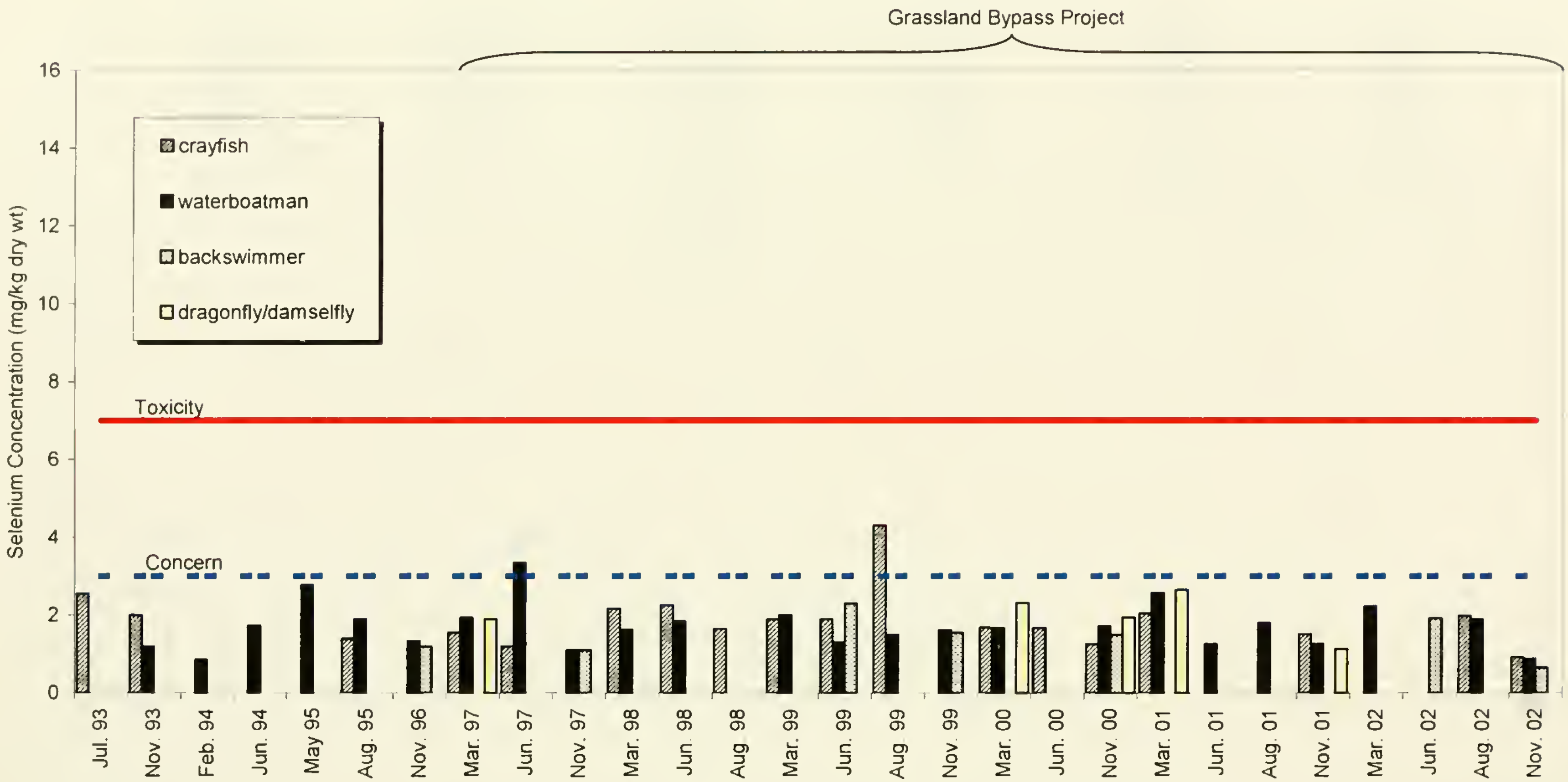


Figure 10. Selenium in small fish in Mud Slough below the San Luis Drain discharge (Site D).

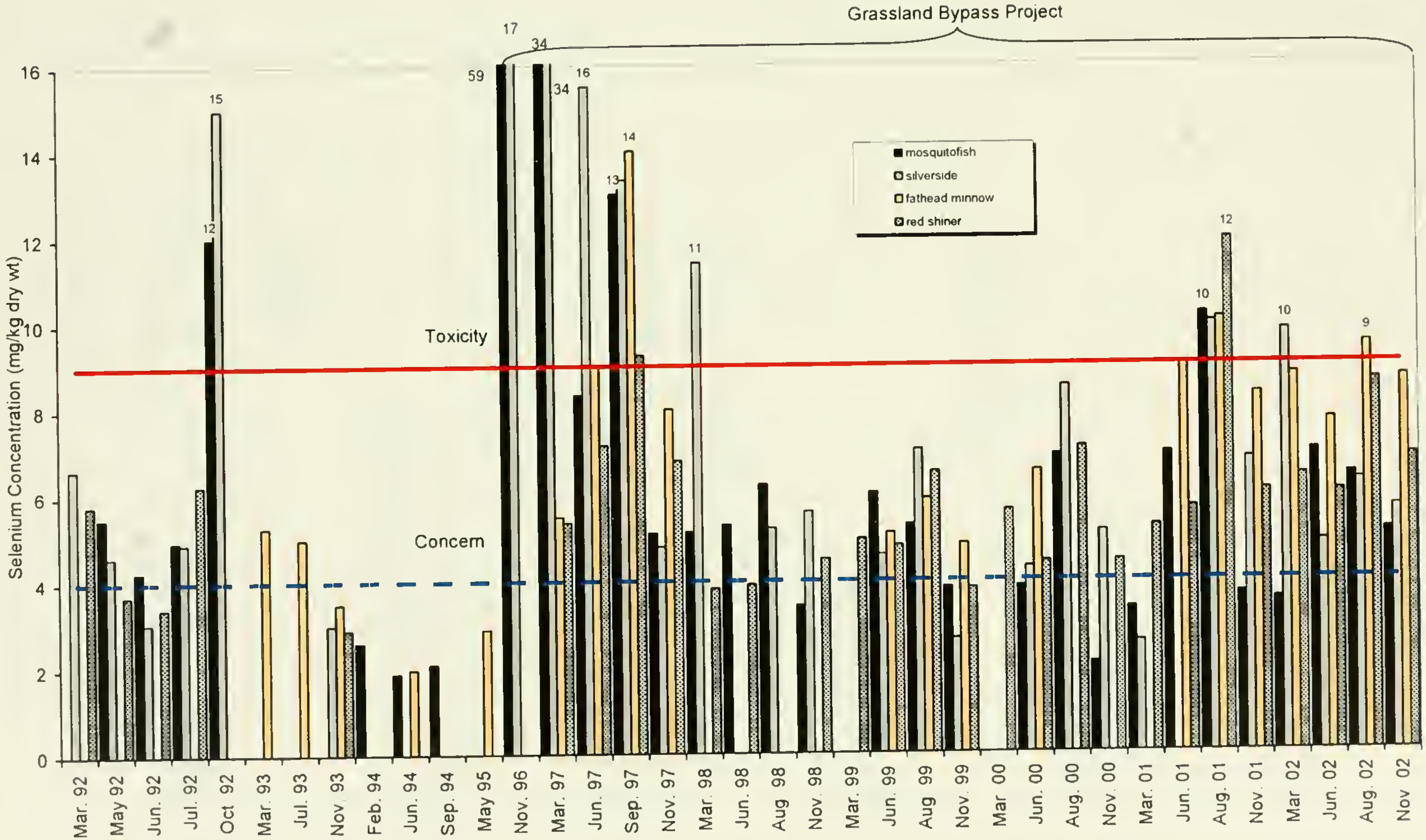


Figure 11. Selenium in medium-size fish in Mud Slough below the San Luis Drain discharge (Site D).

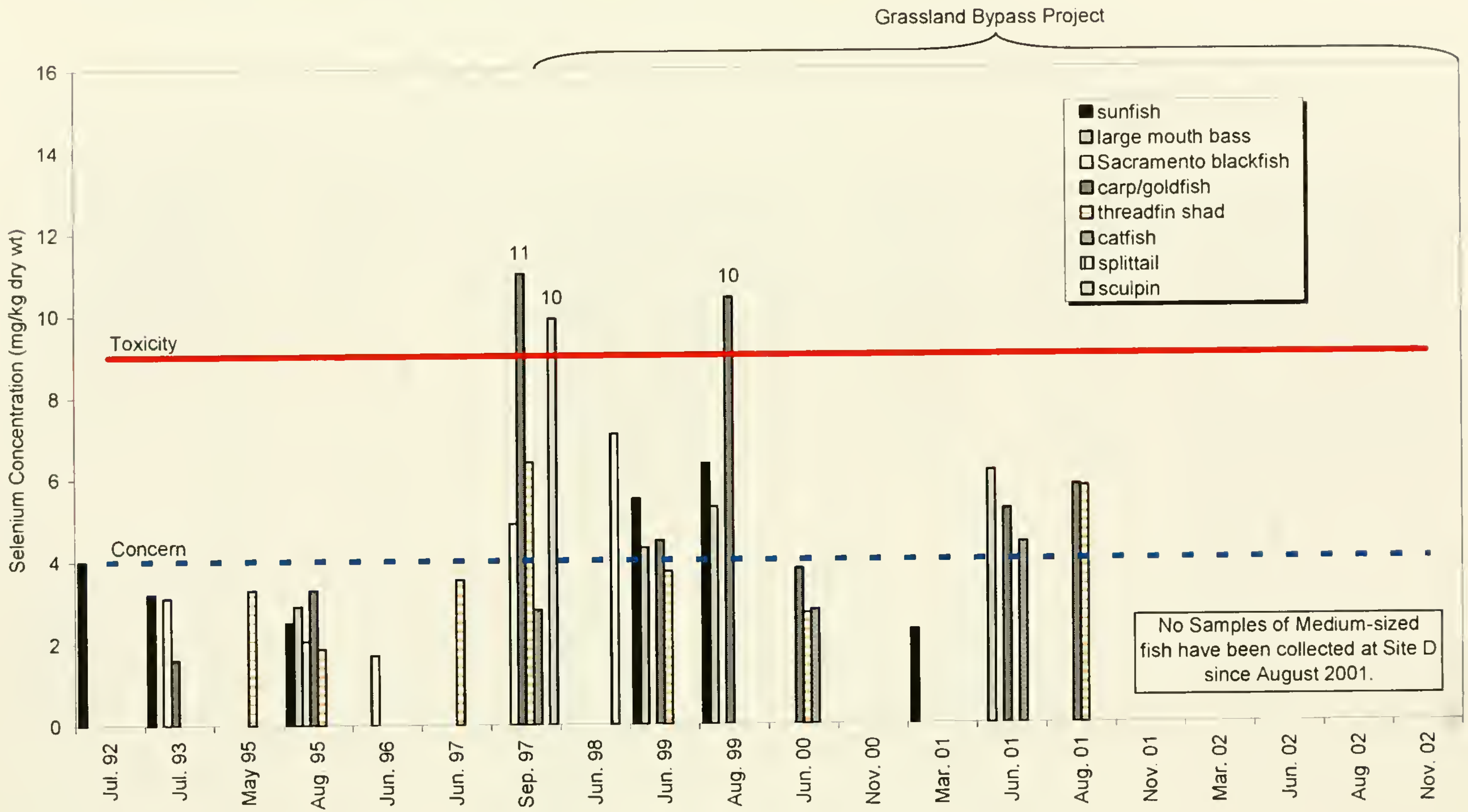


Figure 12. Selenium in bullfrog tadpoles in Mud Slough below the San Luis Drain discharge (Site D).

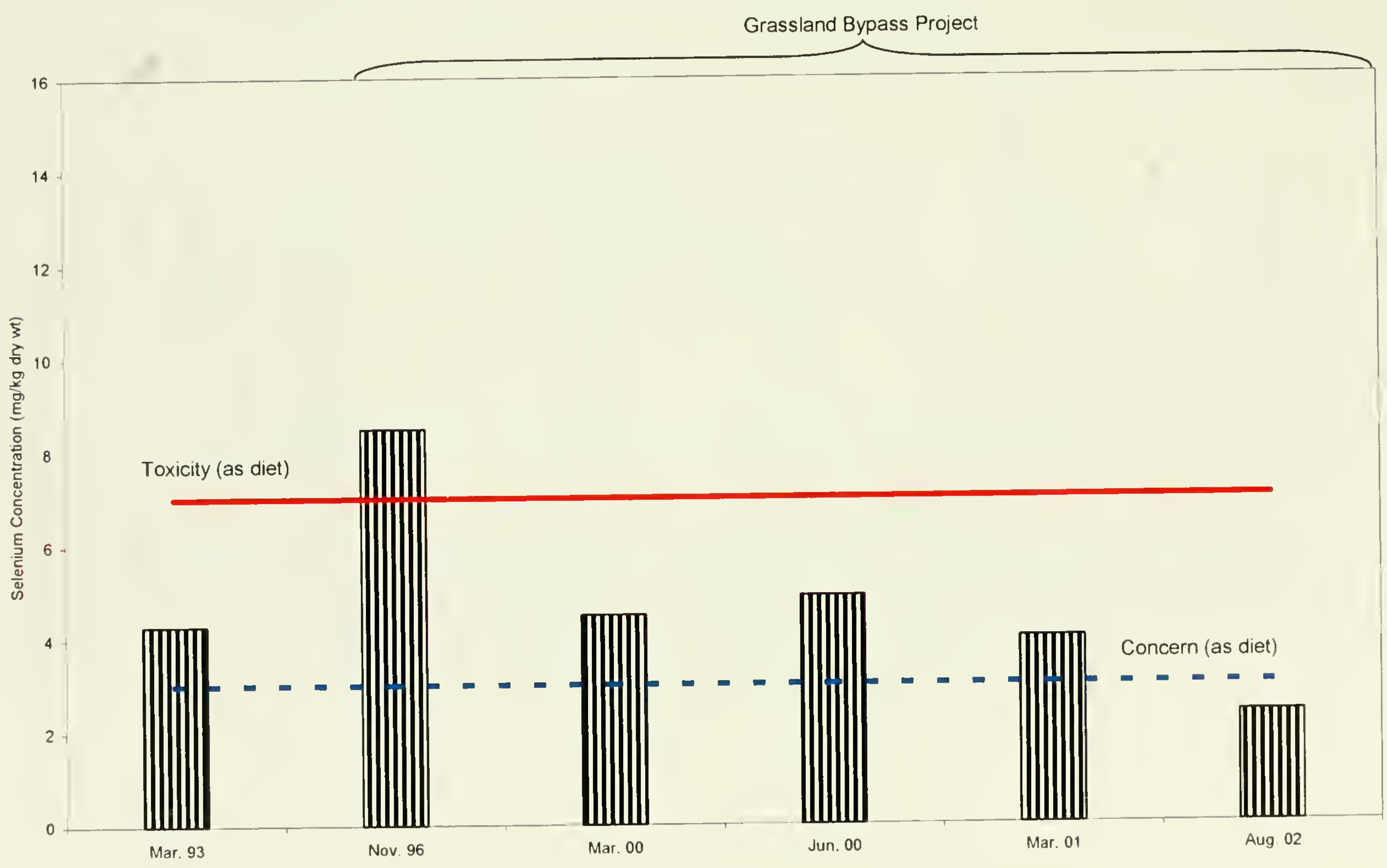


Figure 13. Selenium in invertebrates in Mud Slough below the San Luis Drain discharge (Site D).

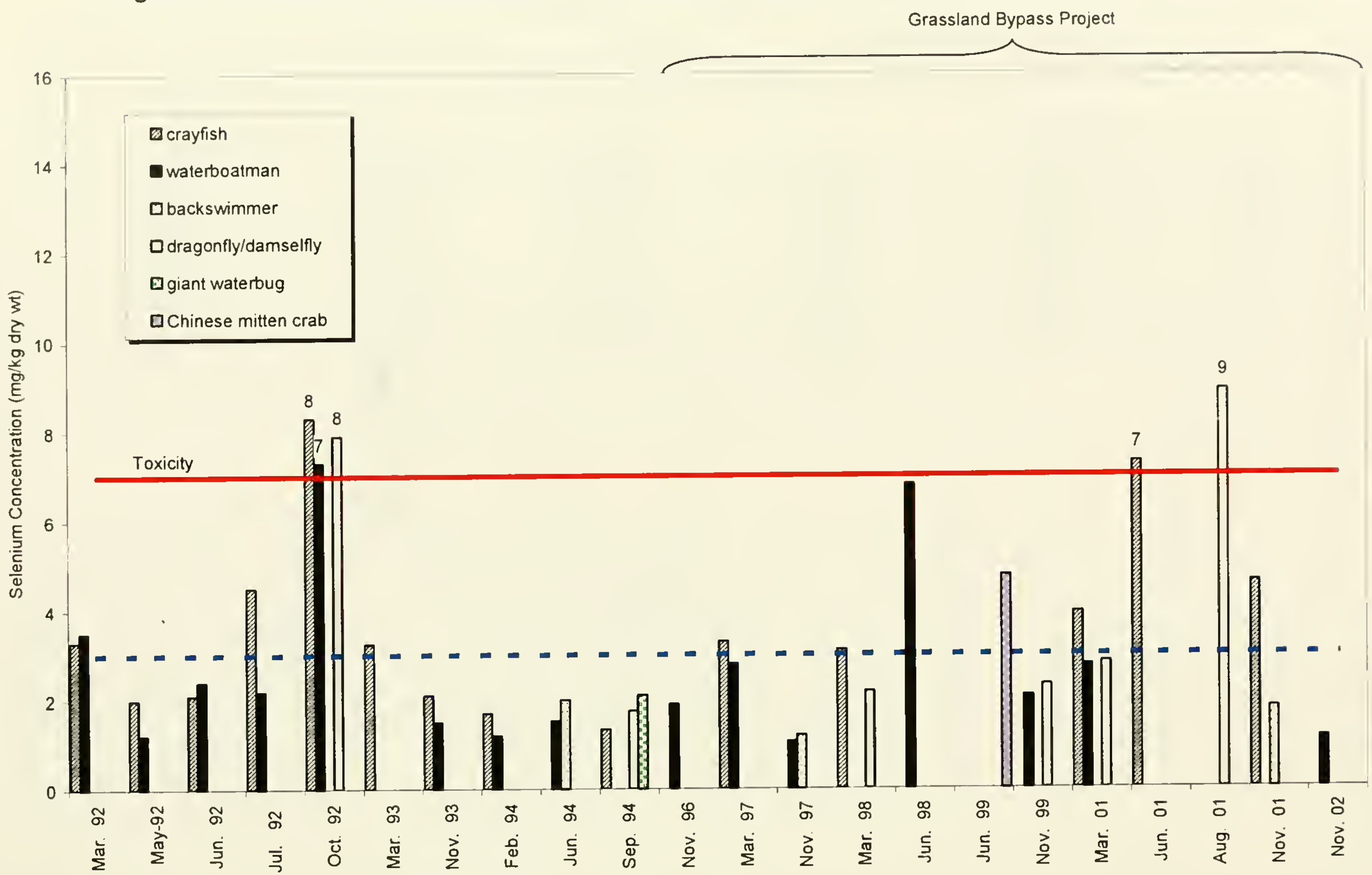


Figure 14. Selenium in small fish in a Mud Slough backwater below the Drain discharge (Sites I and I2).

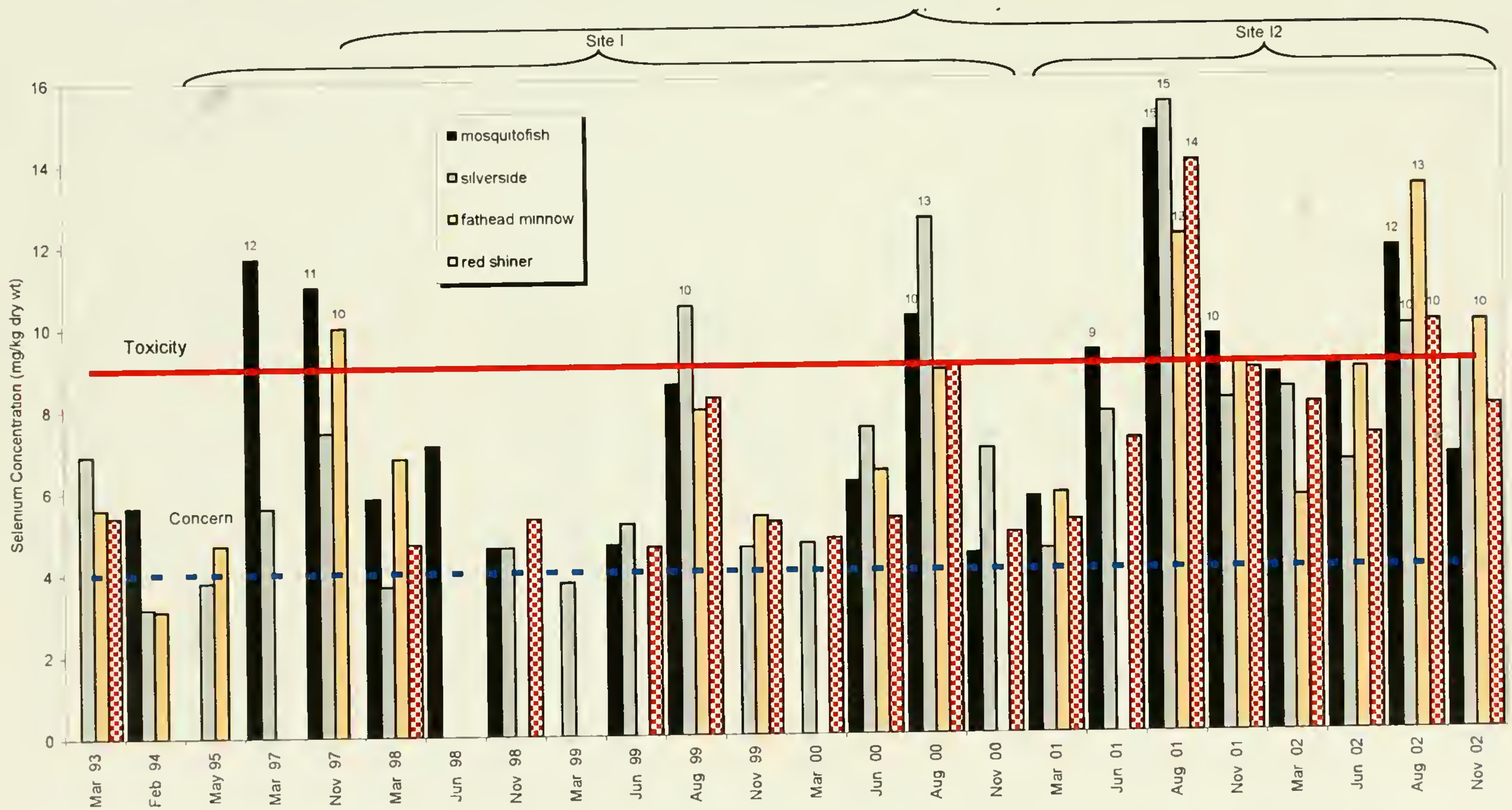


Figure 15. Selenium in medium-size fish in a Mud Slough backwater below the Drain discharge (Sites I and I2).

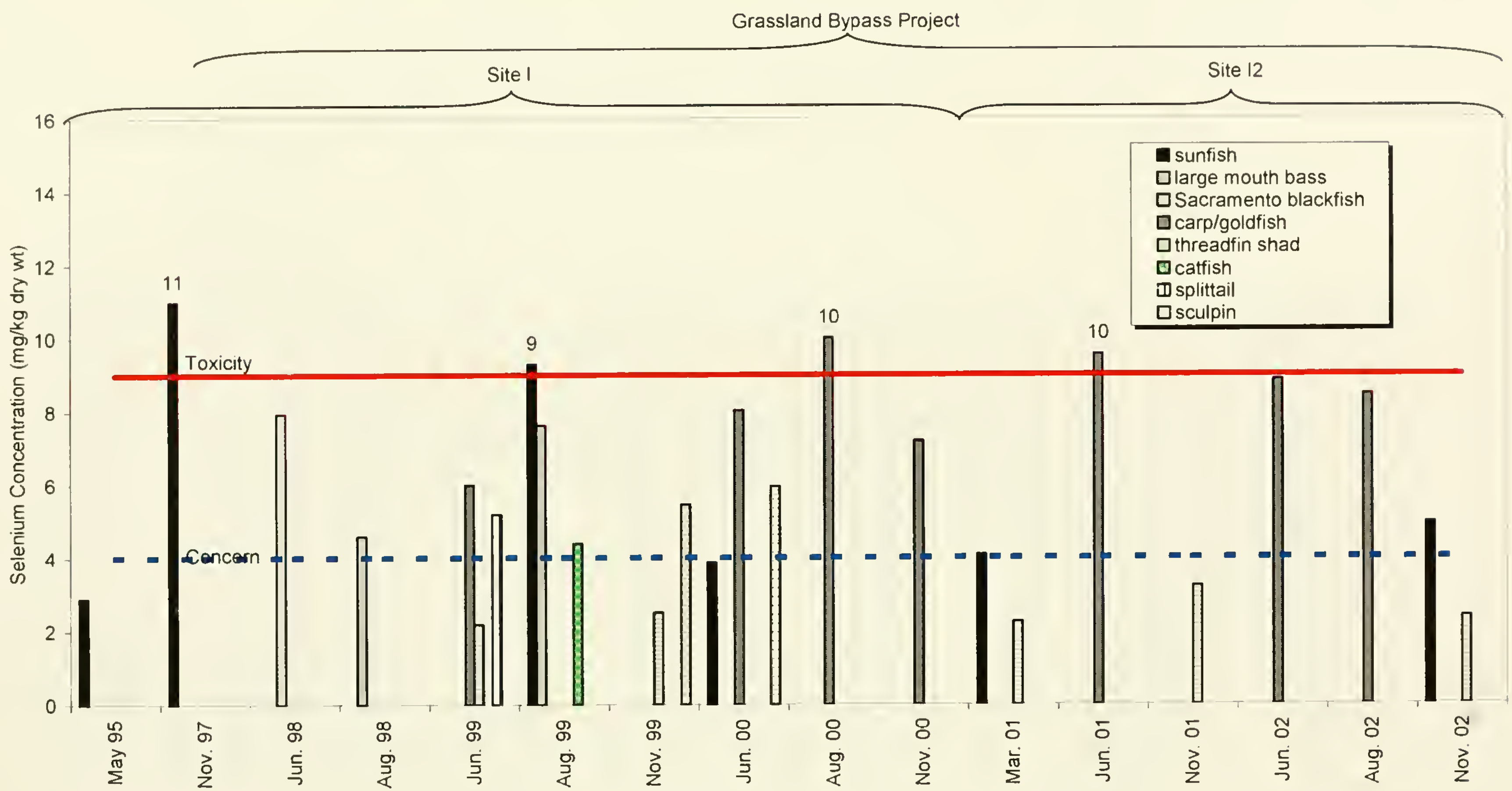


Figure 16. Selenium in invertebrates in a Mud Slough backwater below the Drain discharge (Sites I and I2).

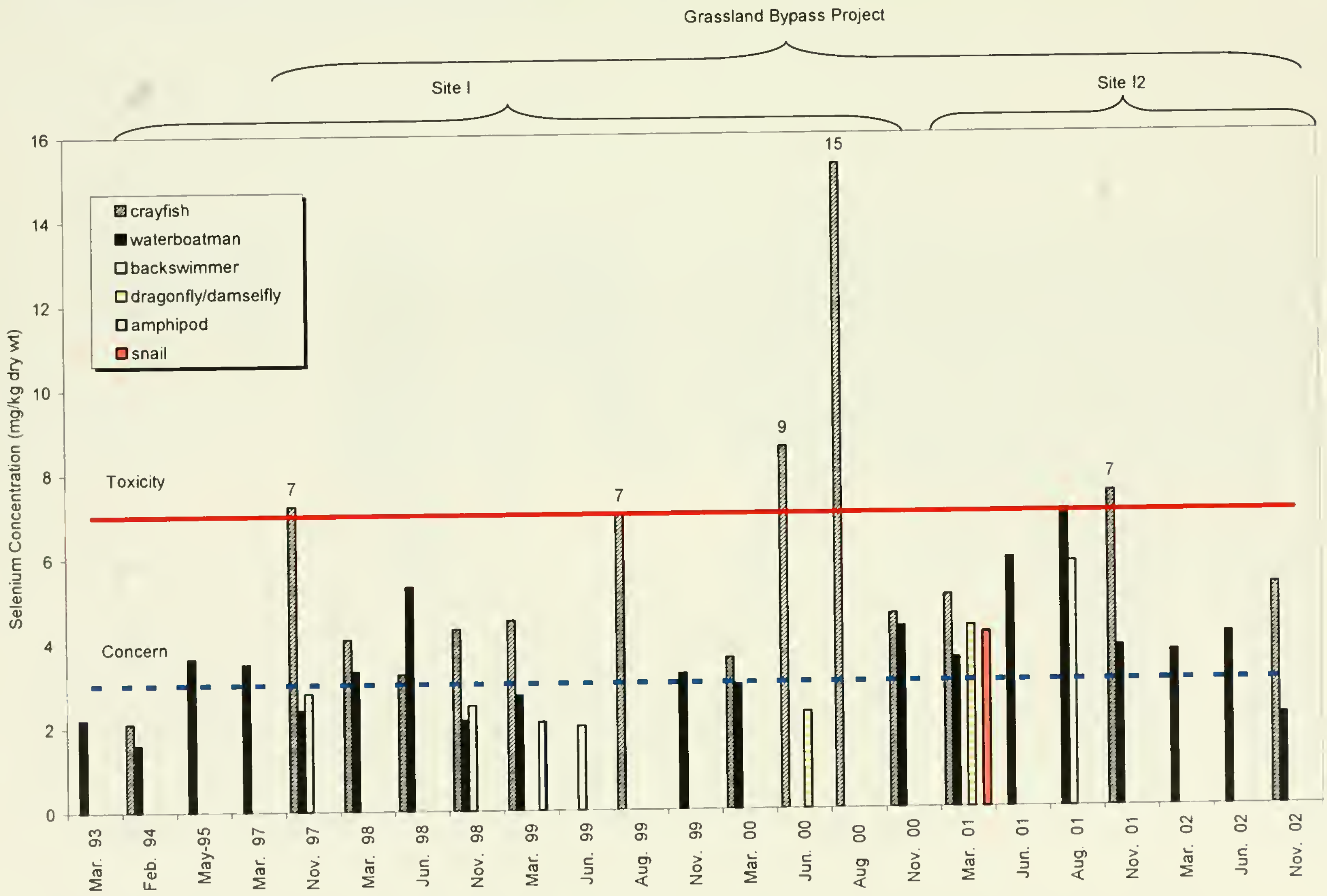
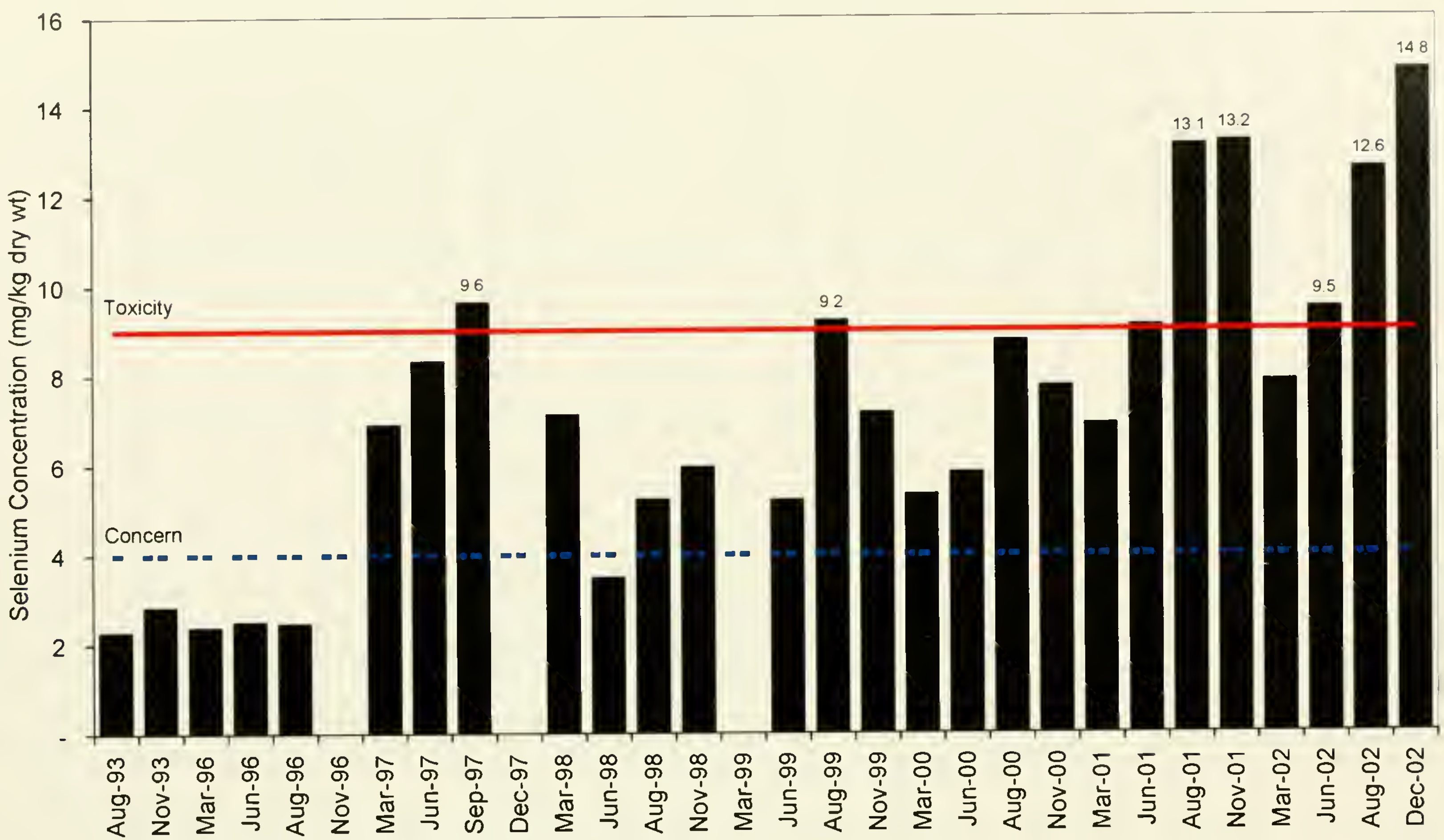


Figure 17. Selenium Concentrations in Whole-Body Fish* Tissue from Mud Slough at Hwy 140 (Site E).



* Mosquitofish *Gambusia affinis* See previous reports for other species

Figure 18. Selenium Concentration in Invertebrates from Mud Slough at Hwy 140 (Site E).

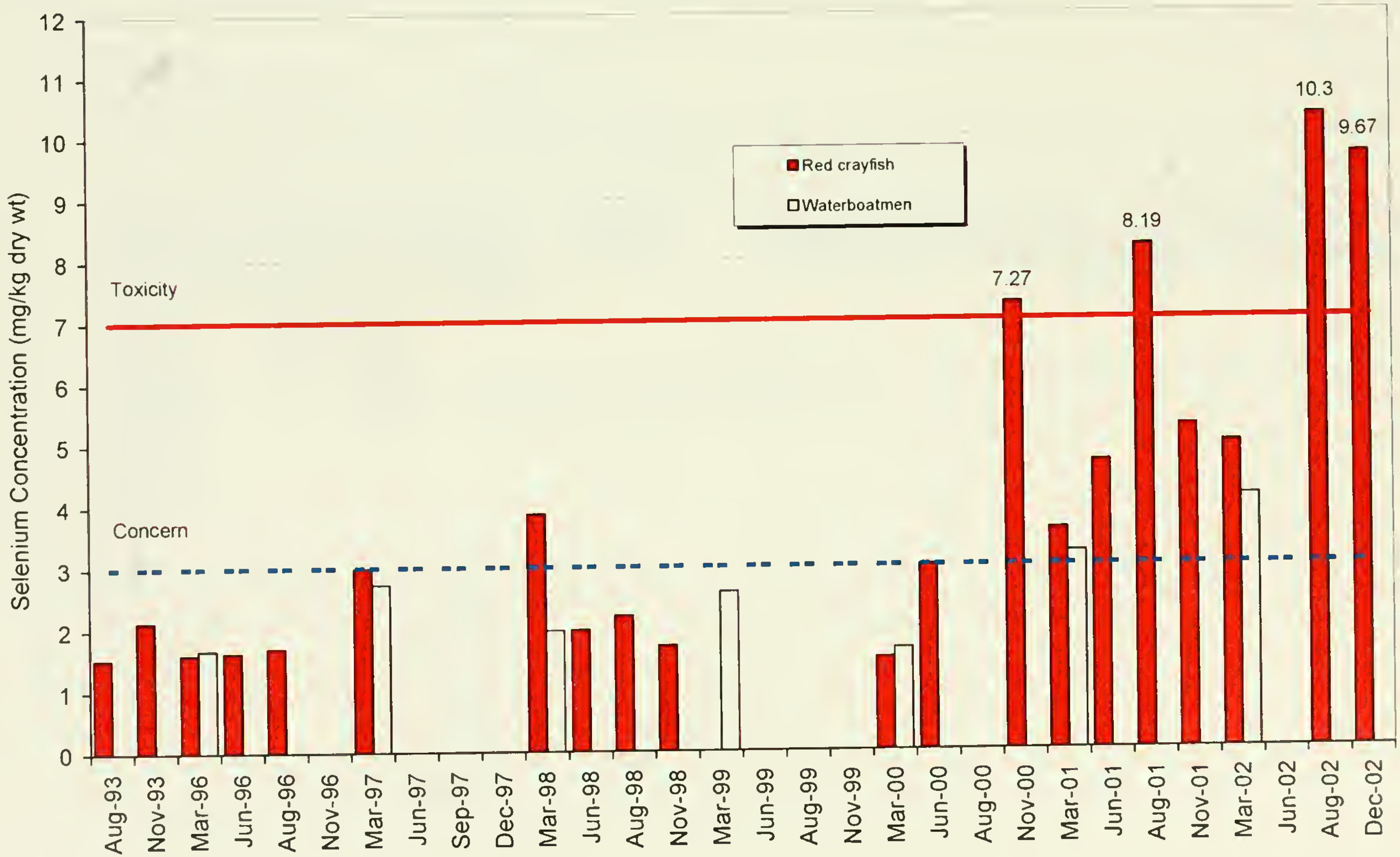
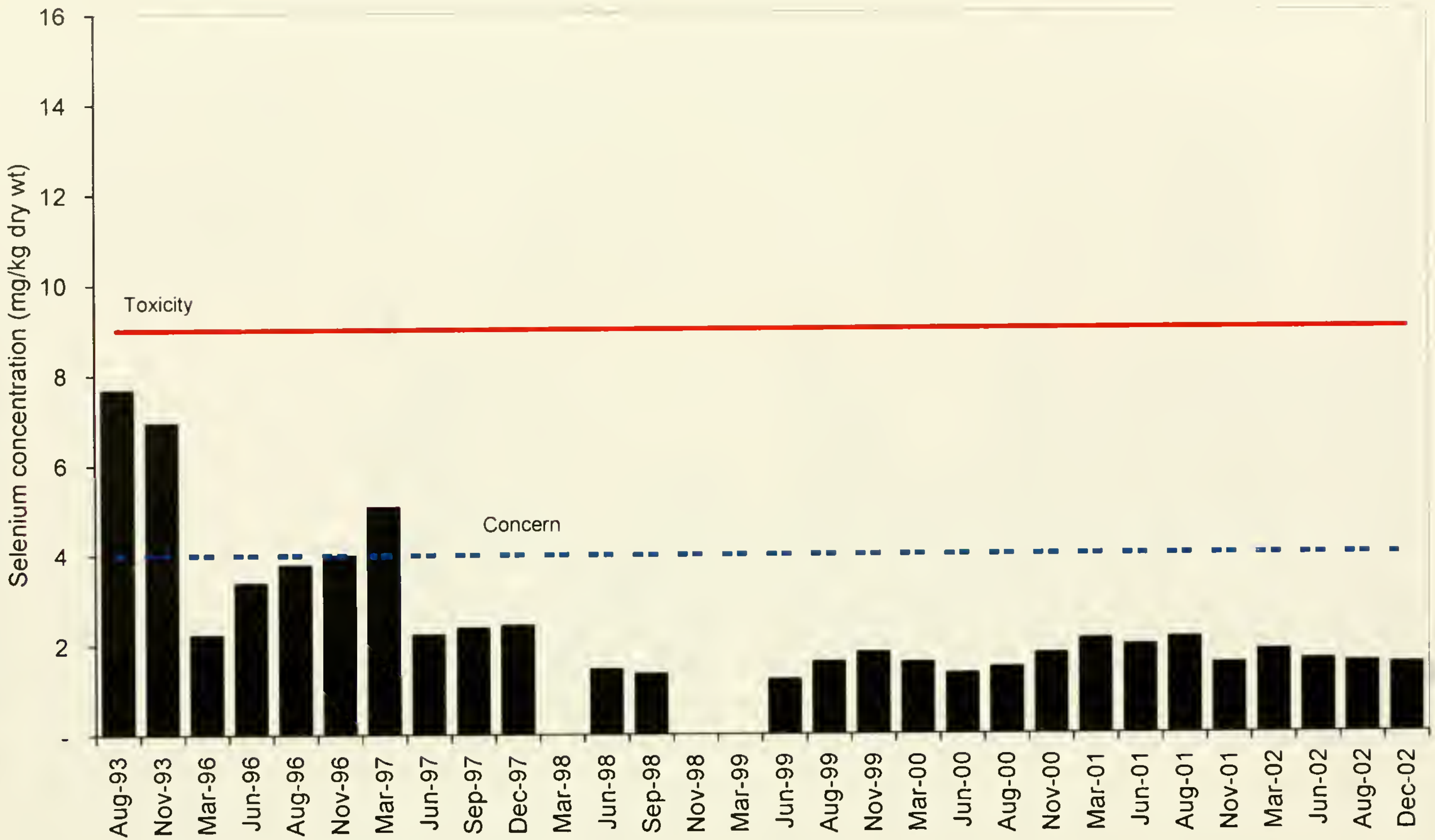


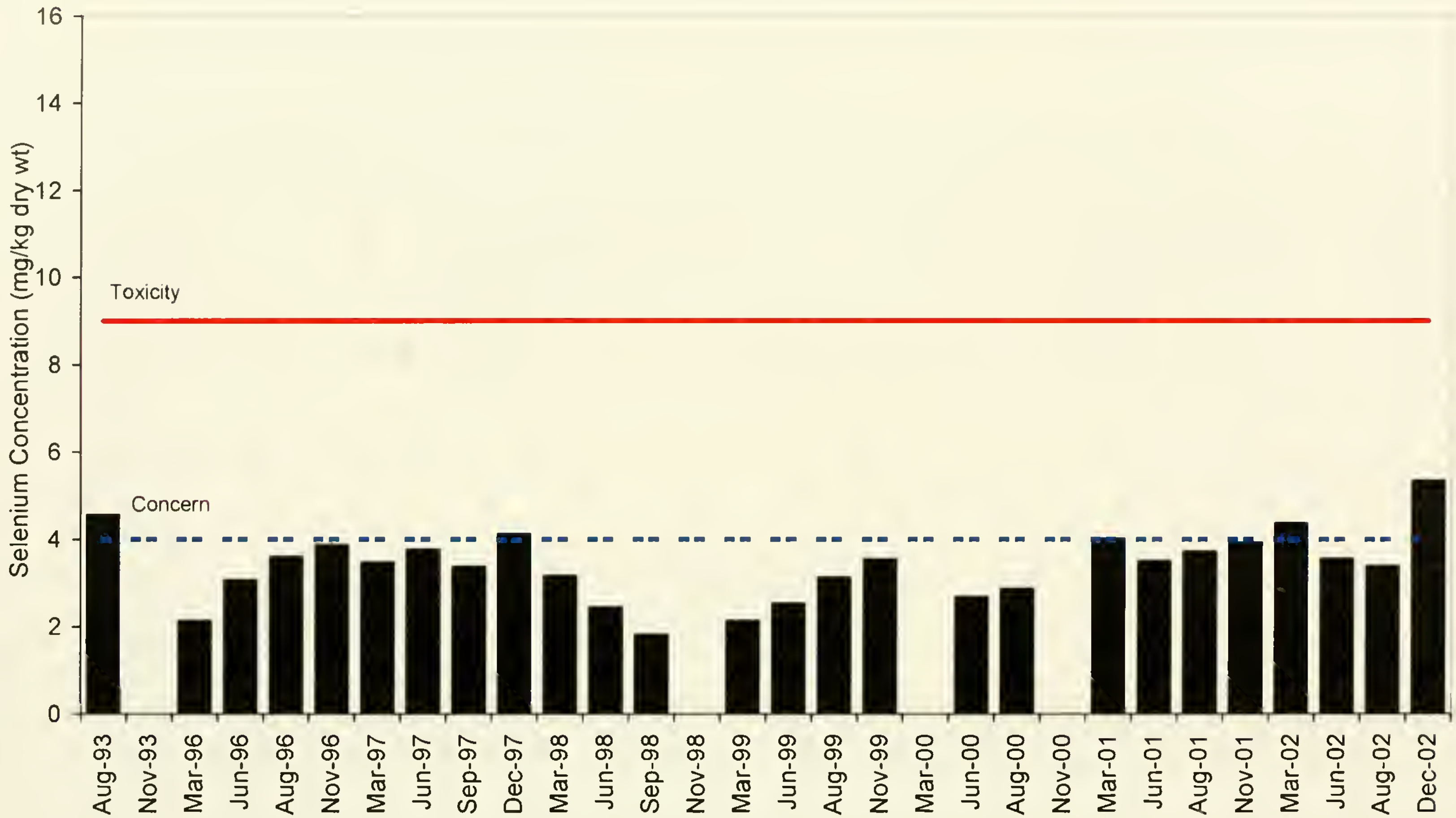
Figure 19. Selenium Concentrations in Whole-Body Fish* Tissue from the San Joaquin River Upstream of the Mud Slough Confluence (Site G).



* Mosquitofish *Gambusia affinis* See previous reports for other species

Figure 20. Selenium Concentration in Invertebrates from the San Joaquin River Upstream of the Mud Slough Confluence (Site G).

Figure 21. Selenium Concentrations in Whole-Body Fish* Tissue from the San Joaquin River Downstream of the Mud Slough Confluence (Site H).



* Mosquitofish *Gambusia affinis* See previous reports for other species

Figure 22. Selenium Concentration in Invertebrates from the San Joaquin River Downstream of the Mud Slough Confluence (Site H).

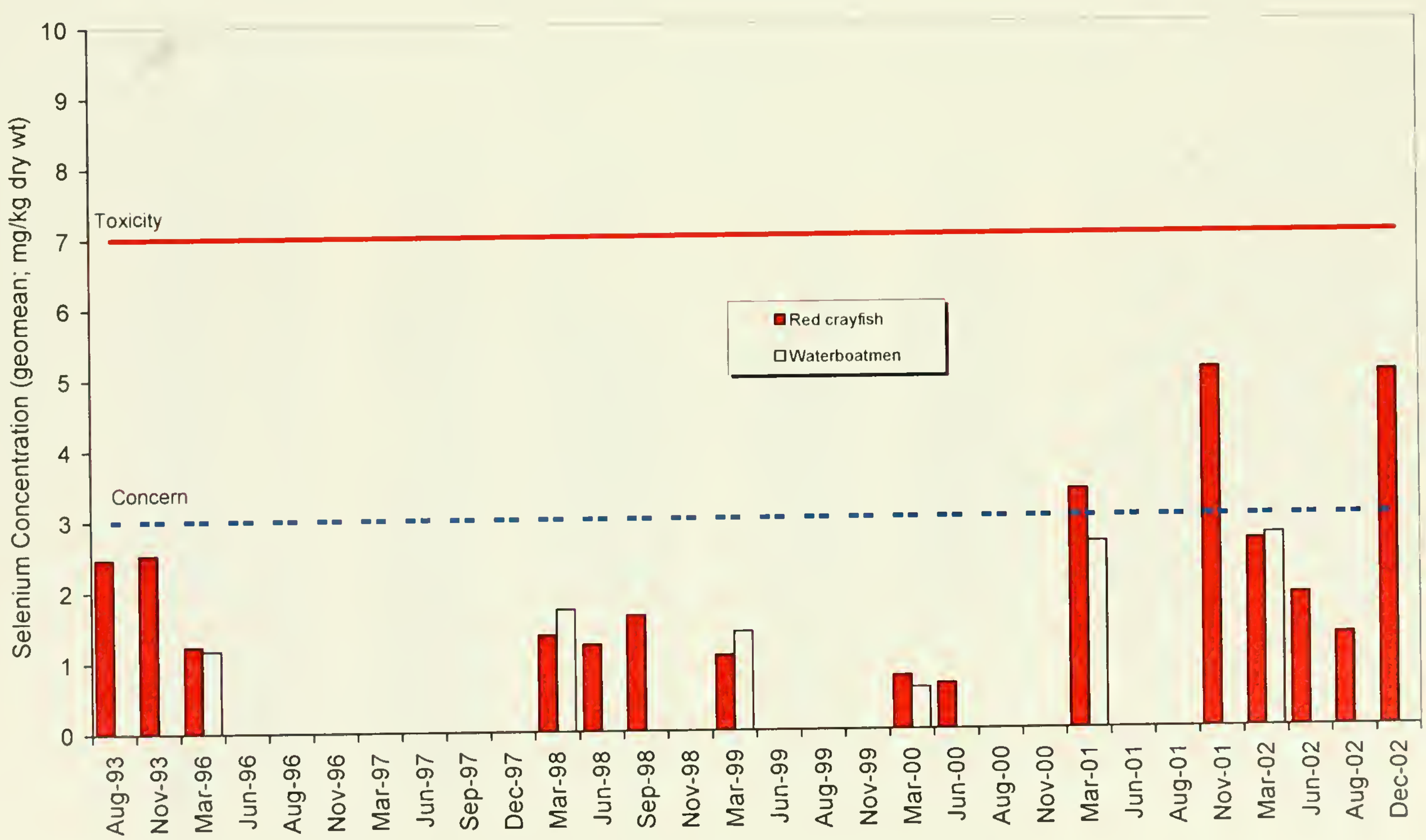


Figure 23. Percent abundance of trophic classifications over time at Site E
August 1993 - December 2002

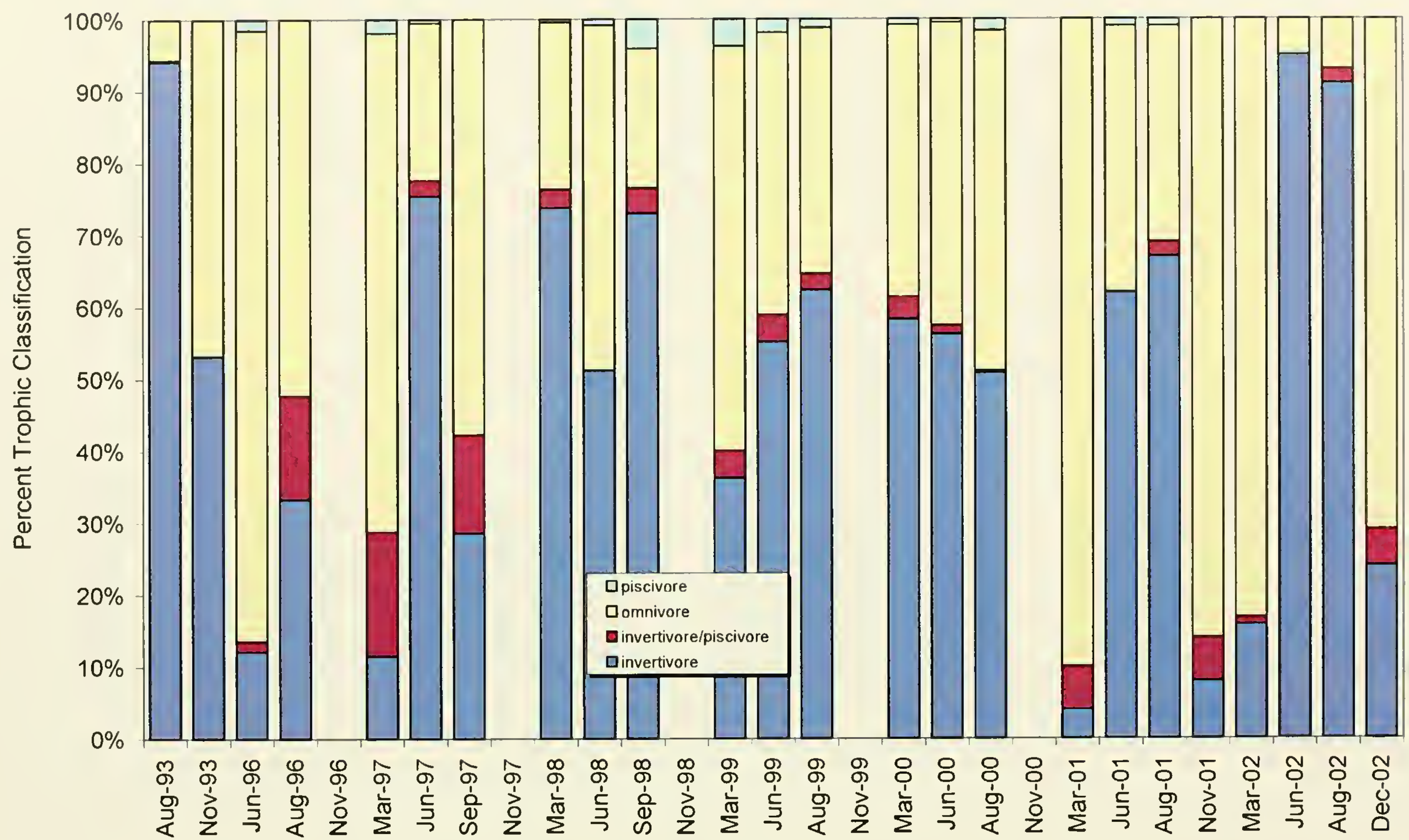


Figure 24. Percent abundance of trophic classifications over time at Site G
August 1993 - December 2002

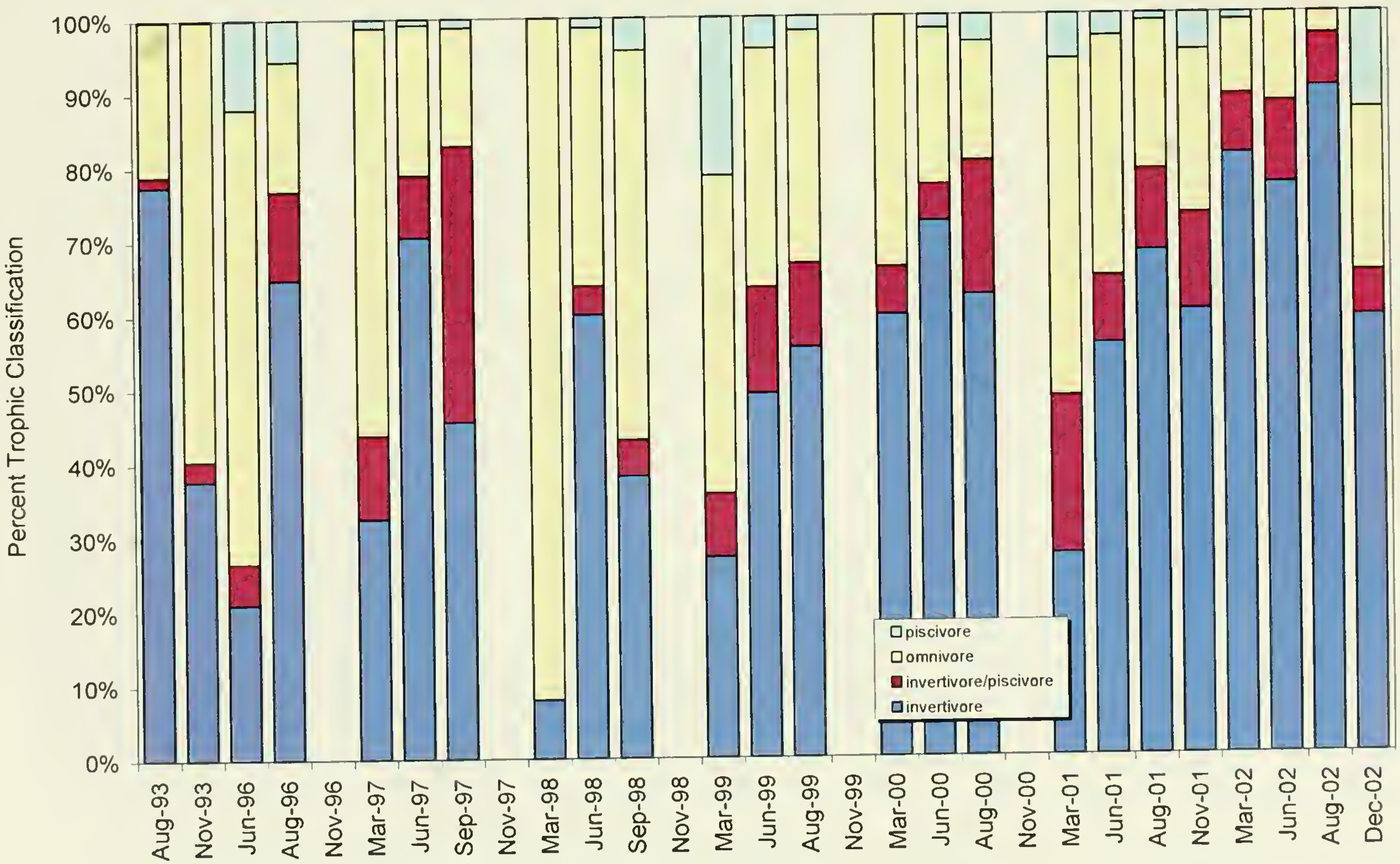


Figure 25. Percent abundance of trophic classifications over time at Site H August 1993 - December 2002

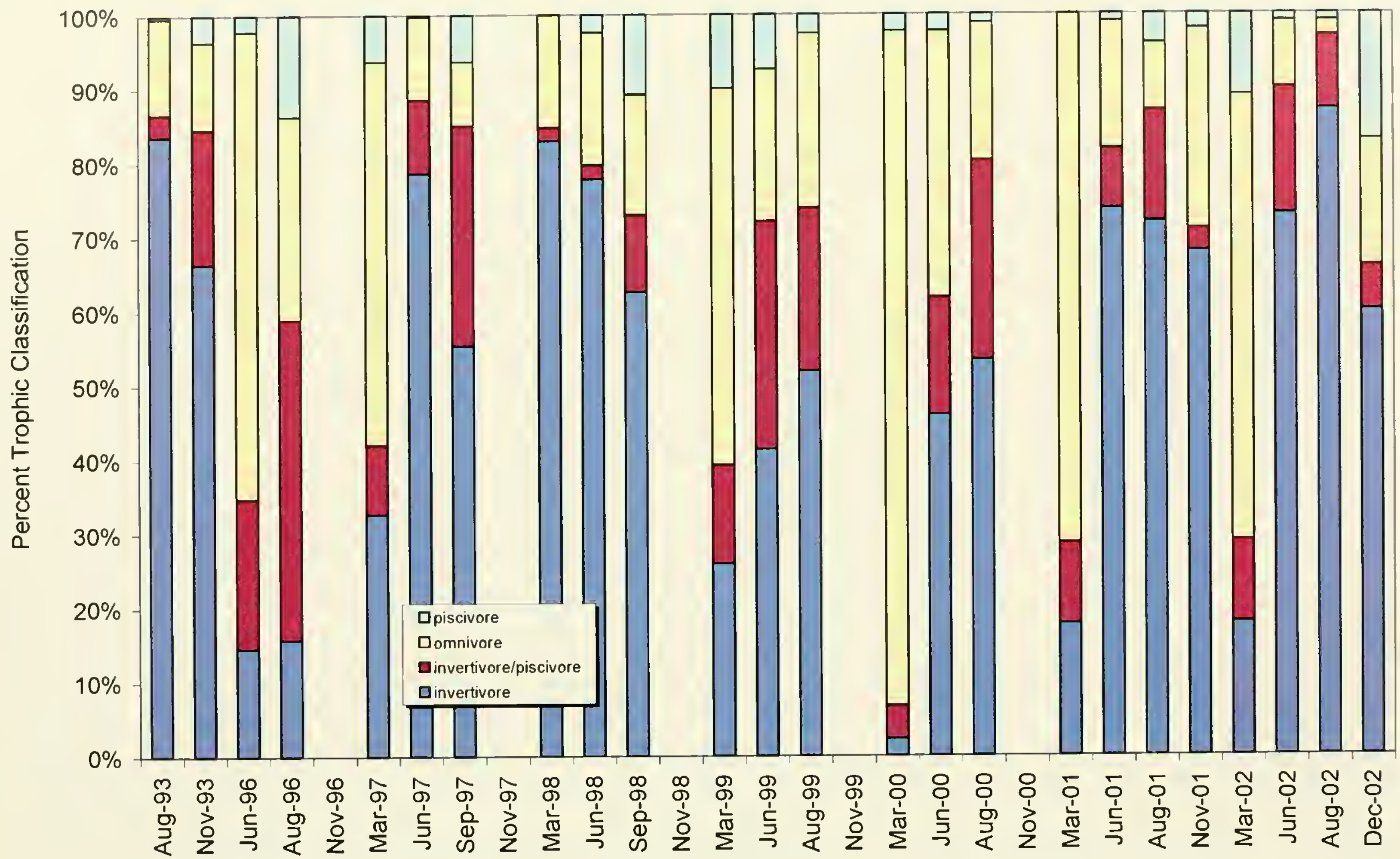


Figure 26. Observed Anomalies*** in all Fish Species Caught at Sites E, G, and H

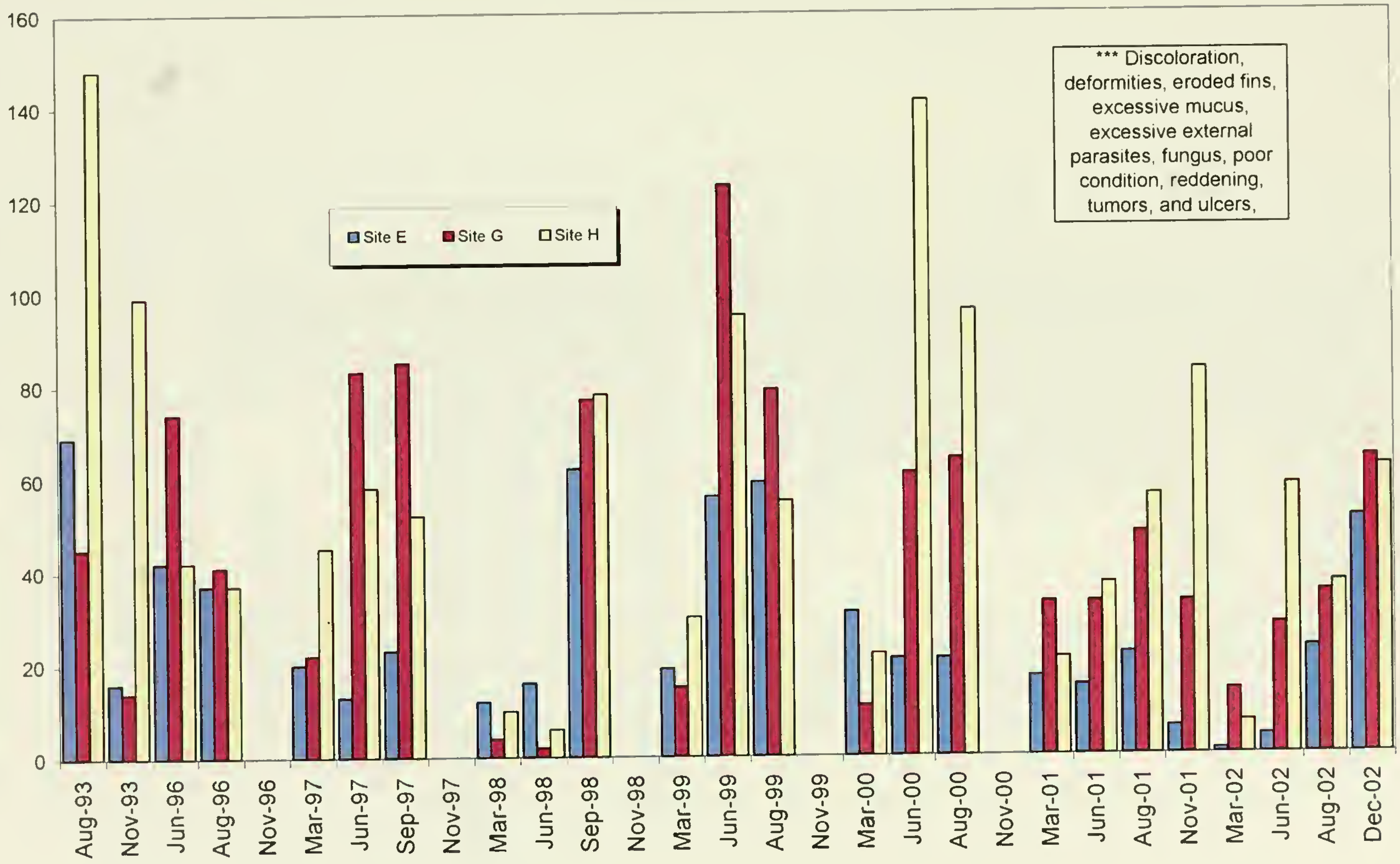
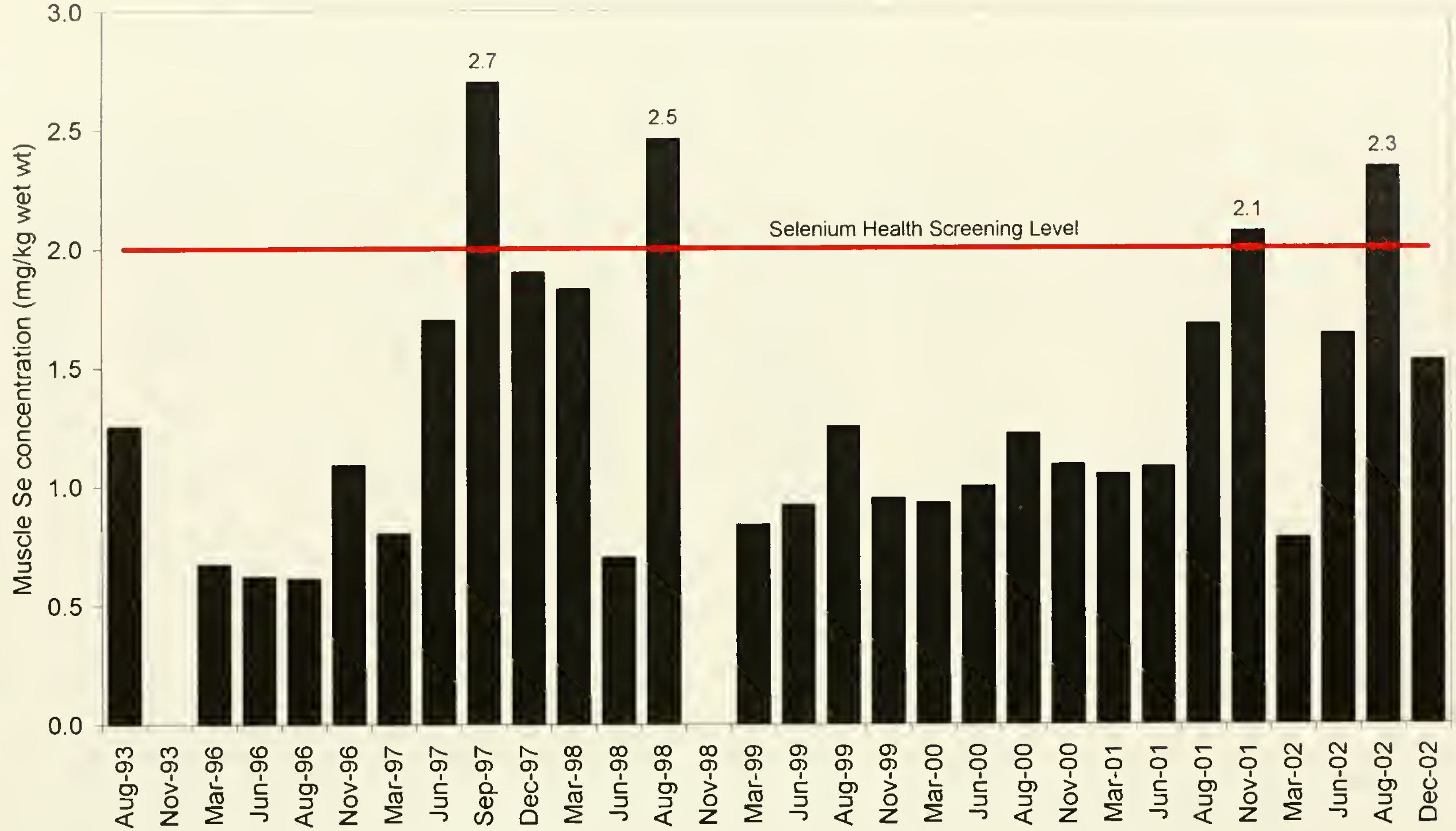
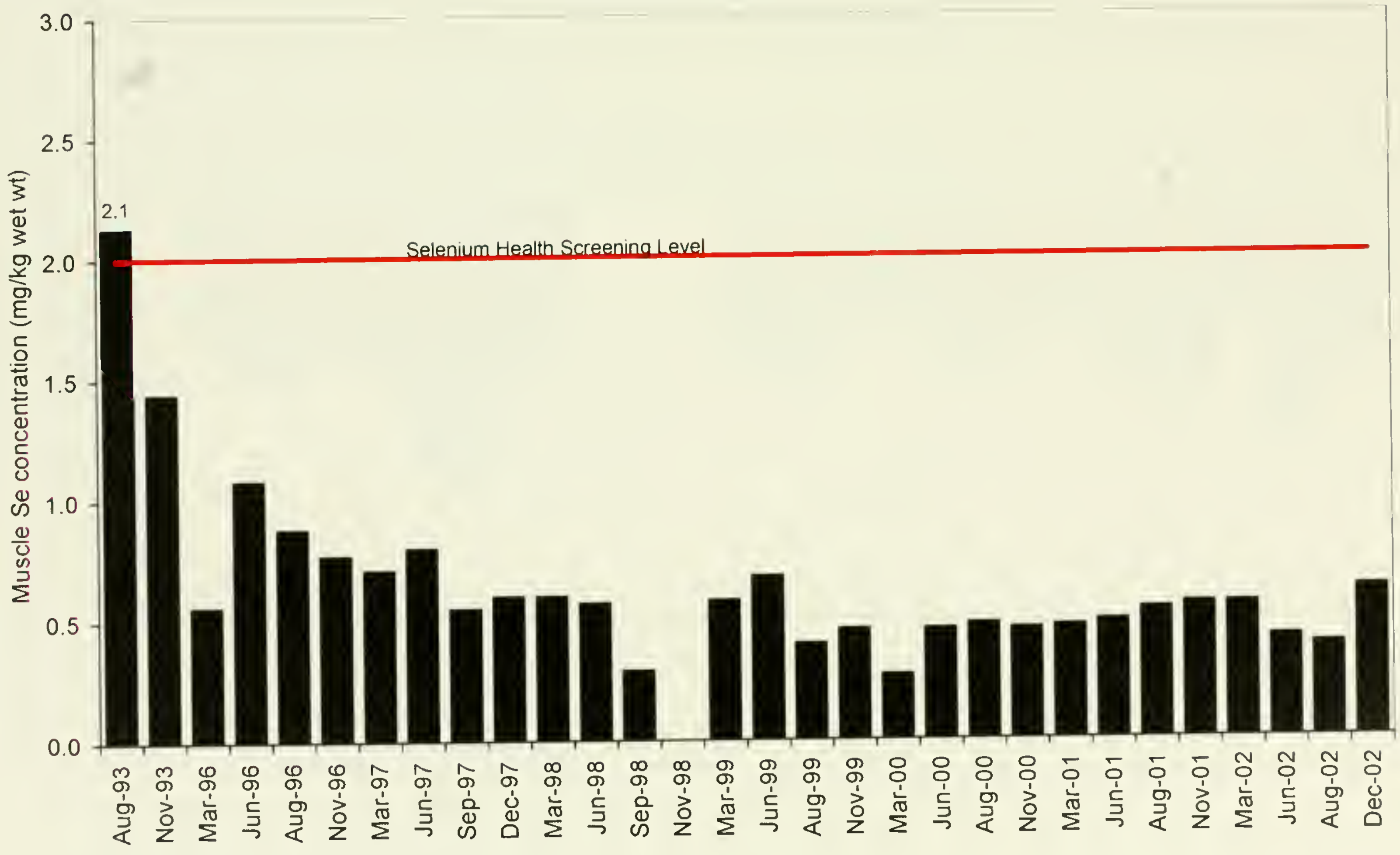


Figure 27. Selenium Concentrations in Fish** Muscle Tissue from Mud Slough at Hwy 140 (Site E).



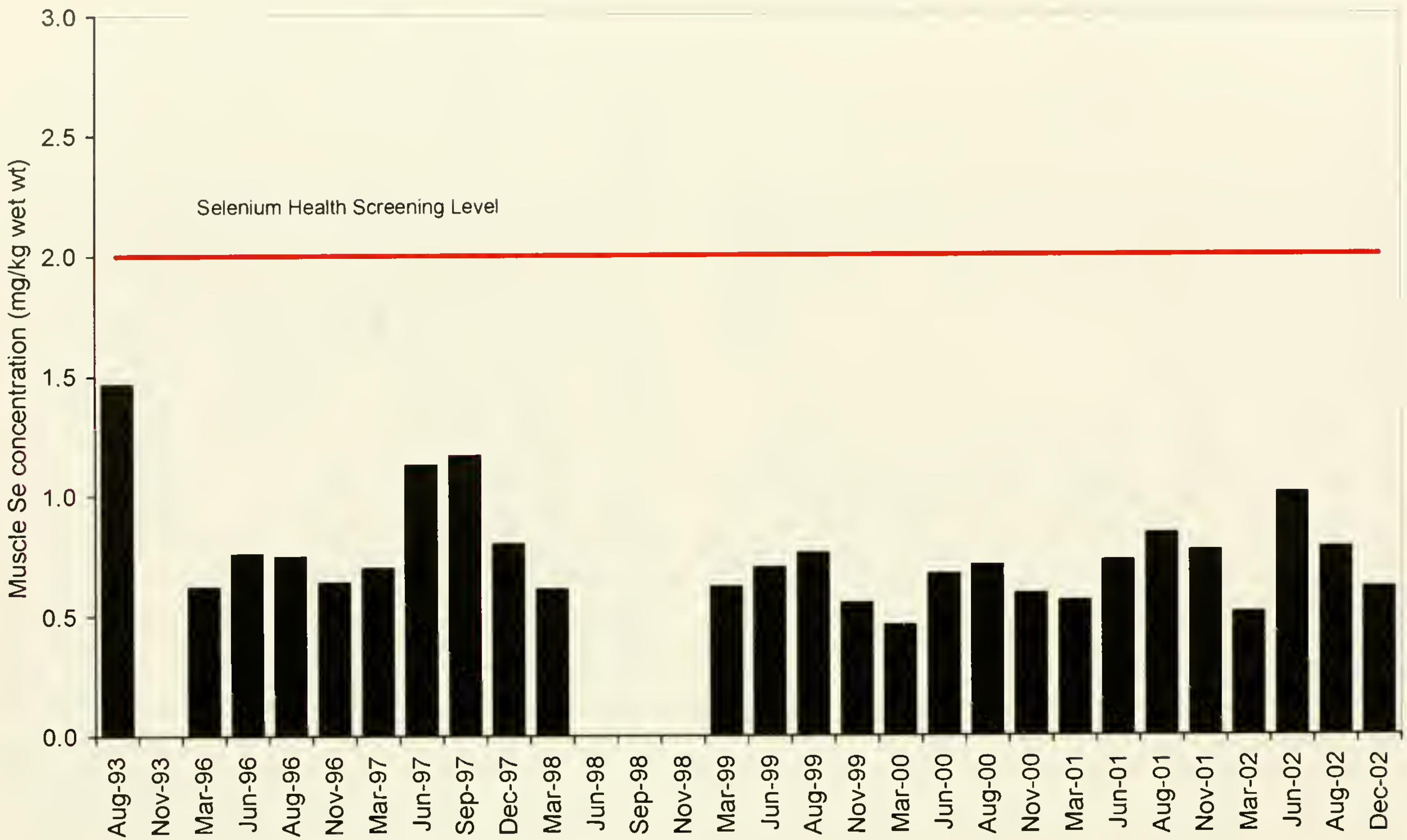
** Carp *Cyrpinus carpus* {See previous reports for other species}

Figure 28. Selenium Concentrations in Fish Muscle Tissue from the San Joaquin River Upstream of the Mud Slough Confluence (Site G).**



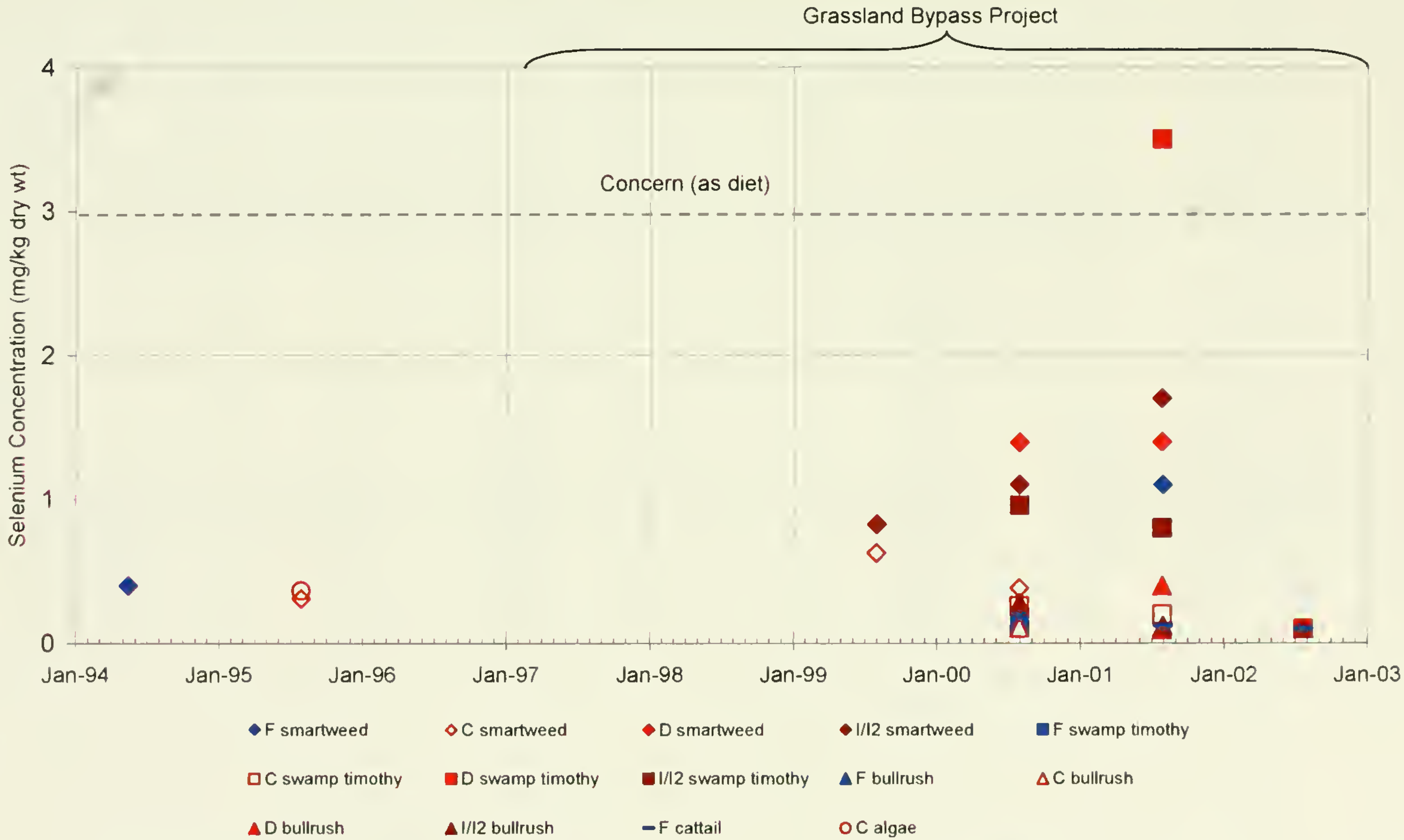
** Carp *Cyrpinus carpus* {See previous reports for other species}

Figure 29. Selenium Concentrations in Fish Muscle Tissue from the San Joaquin River Downstream of the Mud Slough Confluence (Site H).**



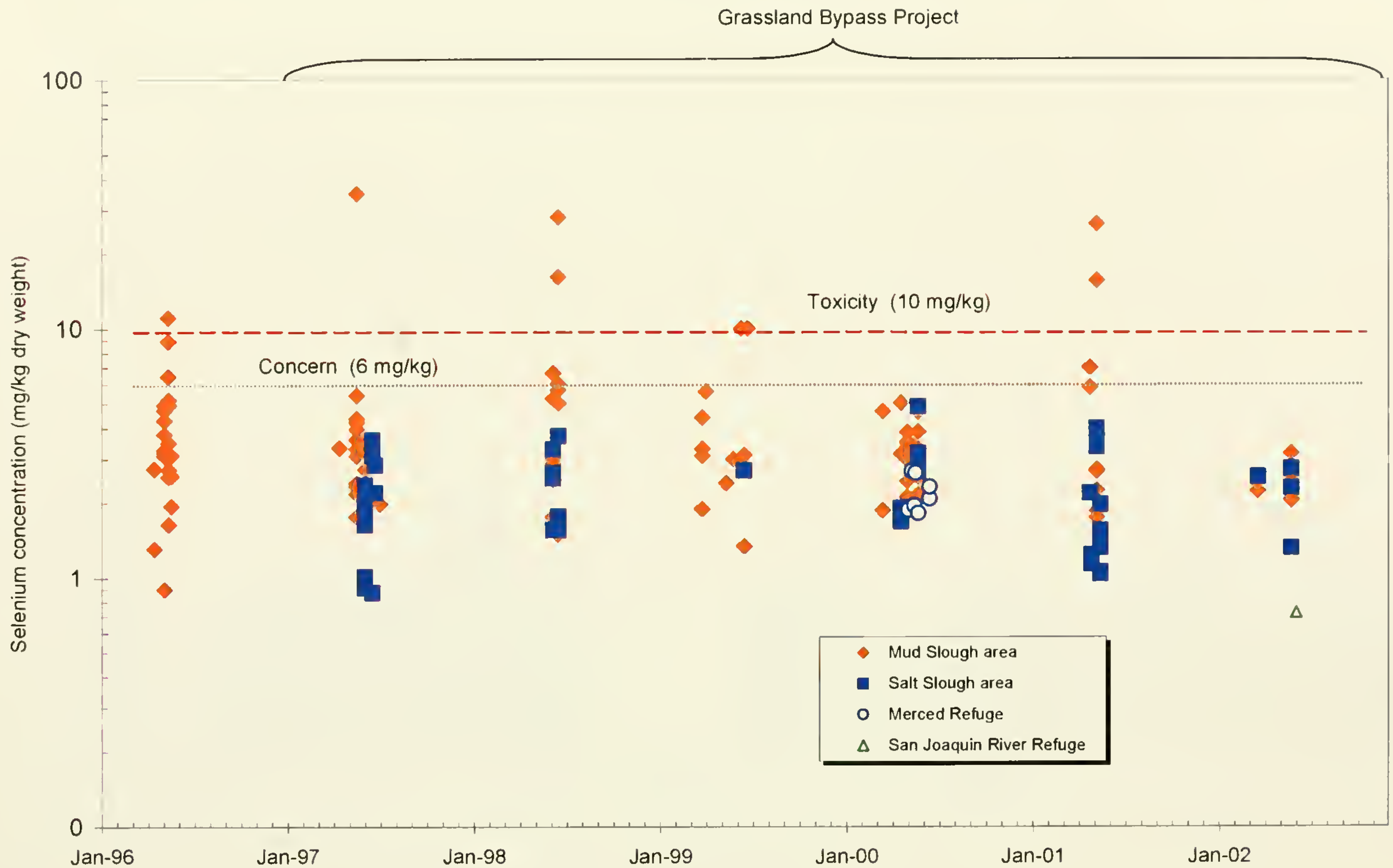
** Carp *Cyrpinus carpus* {See previous reports for other species}

Figure 30. Selenium in plants (seed heads where applicable)



All samples of vegetation collected in August of 2002 at Sites F, C, D and I2 were below the reporting limit (0.20 mg/kg, dry wt.) for selenium.

Figure 31. Selenium in bird eggs



Toxicity Testing for the Grassland Bypass Project

October 1, 2001 – December 31, 2002

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Introduction

The objective of the laboratory toxicity testing is to evaluate the potential toxicity of water-borne contaminants within the Grassland Bypass Project (GBP) area using standardize bioassay protocols conducted under controlled environmental conditions. The laboratory toxicity tests evaluate one species within each of three trophic levels using short-term chronic testing procedures (7 or 4 days) and lethal (survival) and non-lethal (growth or reproduction) endpoints (USEPA 1987; 1994). The test species are *Selenastrum capricornutum* (alga), *Daphnia magna* (water flea), and *Pimephales promelas* (fathead minnow).

The testing is not specific for any single chemical exposure, but rather demonstrates the net effect of only waterborne contaminant exposures in the site waters on the selected test species. During toxicity testing, test species are fed a controlled diet that is unrelated to field sources of food. For this reason, toxicity testing is not expected to detect selenium toxicity in invertebrates and fish because the main route of exposure in these groups of organisms is through the food they eat. However, selenium toxicity in algae is through direct exposure from water and thus toxicity testing may detect selenium toxicity in algae.

Tests are conducted at the screening level, comparing the ambient water to 100% test water. If significant toxicity is observed, definitive tests (dilution series) may be conducted. Water samples are collected from Stations B, C, D, and F for each monthly testing period. The Delta-Mendota Canal station is the control site. Additionally, selenium concentrations were also determined from water samples collected for each toxicity testing event by the U.S. Bureau of Reclamation (USBR) contract laboratories. However, in-situ chronic toxicity testing using caged fathead minnows has been eliminated during the course of the program, as well as measurement of selenium bioaccumulation in algae.

The toxicity program is conducted by Block Environmental Service's (BES) Bioassay Laboratory Division under the guidance of the San Luis and Delta-Mendota Water Authority. Technical assistance, quality assurance/quality control (QA/QC), and program oversight is provided by the U.S. Environmental Protection Agency (USEPA) and USBR. The toxicity program is carried out monthly.

During the past five years (Phase I; October 1996 to September 2001), the monthly collected data was used to evaluate potential adverse effects to test organisms exposed to agricultural drain water from the San Luis Drain (SLD; Site B) and Mud Slough (Site D). An evaluation was also made for Mud Slough (Site C) above the influence of the SLD and for Salt Slough (Station F), which represent the water in the Grassland wetland water supply channels.

The current phase of the Grassland Bypass Project (GBP), Phase II, was initiated in October 2001 and continues through December 31, 2009. Changes implemented for Phase II included the following: 1) No in situ water chemistries will be taken on day 0 of each testing period, and 2) No sulfate analysis will be done on any of the site samples.

In Phase II (as with Phase I), each toxicity test was performed using three separate grab samples collected on Day 0, Day 2, and Day 4 of the 7-day testing period. Site results were then compared with responses to ambient control water samples collected from the Delta Mendota Canal (DMC). The data were then used to assess contaminant exposures both temporally and spatially within the GBP area and to identify trends.

The monthly data for the fifteen-month study period [2] are presented in this chapter and are compared graphically with the previous five years (Phase I).

Materials and Methods

Toxicity tests were conducted monthly on three species from three different trophic levels using the short-term chronic testing procedures, and evaluating acute and chronic endpoints (USEPA, 1987; 1994).

These tests are:

- Daphnid invertebrate (*Daphnia magna*) Short-term Acute Survival
- Fathead Minnow (*Pimephales promelas*) 7-Day Acute Larval Survival
- Daphnid invertebrate (*Daphnia magna*) Short-term Chronic Reproduction
- Fathead Minnow (*Pimephales promelas*) 7-Day Chronic Larval Growth
- Freshwater algae (*Selenastrum capricornutum*) 96-Hour Growth Test

The tests were conducted for five different sampling sites (Sites B, C, D, F and the DMC) for a total of 25 tests each month. Each test was performed using 100% sample versus the DMC ambient control except for Site B. The *Selenastrum capricornutum* growth tests also included definitive tests, using a 0.5 dilution factor. The concentration series for this test was: DMC control, 12.5%, 25%, 50%, 75% and 100% sample water.

The toxicity tests use 3 water samples collected on Day 0, Day 2 and Day 4 of the 7-day testing period. Grab samples were collected from Sites B, C, D, F, and the DMC for each monthly testing period. All toxicity test results were analyzed using the software program Toxicity Information Management System (TOXIS, Version 2.5, EcoAnalysis, Inc.). TOXIS was used to determine if there was a statistically significant reduction ($p<0.05$) in the site test response versus the ambient control response during each monthly testing period (USEPA, 1994).

In order to assess independently the health of the test organisms and laboratory performance, a concurrent reference toxicant test was conducted for each of the test species during the monthly testing periods. The reference toxicant test was conducted using a dilution series of the toxicant in laboratory control water. The toxicity endpoints from the reference toxicant tests of each test method were plotted on a running control chart of the last 20 tests. The mean and upper and lower control limits (± 2 standard deviations) were recalculated with each successive test result. The outliers, values falling outside the upper and lower control limits, and trends of increasing or decreasing sensitivity, were identified. At the $p= 0.05$ probability level, one in 20 tests (5%) would be expected to fall outside of the control limits by chance alone.

Sub-samples of the three grab samples for each site were analyzed for selenium by the USBR contract laboratories. Other laboratory analyses (performed by BES) included conductivity, total suspended solids, dissolved oxygen (DO), pH, salinity, alkalinity, hardness, temperature, ammonia, and total chlorine.

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Except as noted above, specific sampling and testing protocols for each procedure may be found in the Monitoring Program for Use and Operation of the Grassland Bypass Project, Phase II (USBR et al., June 2002) and the Quality Assurance Project Plan (USBR et. al., August 2002).

Results

Data for Phase 1 of the toxicity monitoring program may be found in the 2000 – 2001 Annual Report (USBR et. al, 2003). The results from the first fifteen months of the Second Phase of the toxicity monitoring program are presented in Tables 1 through 21. Figures 1 through 21b present the data graphically.

There were fifteen monthly laboratory toxicity test periods between October 2001 and December 2002. These results are listed in Tables 1 through 6. Tables 7 – 10 are contain summaries of occurrences of statistically significant results over the course of the project.

Water chemistry data measured in the laboratory comparing each of the stations are found in Tables 11 through 21.

Laboratory Toxicity Testing

Daphnid invertebrate (*Daphnia magna*) Short-term Acute Survival

The *Daphnia magna* short-term acute survival results are presented in Table 1 and in Figures 1, 6, 11, and 16. There were two tests with statistically significant ($p<0.05$) reductions in survival: August 2002 (Site F) and November 2002 (Site B).

During the November 18, 2002 test, the laboratory analyses of the Site B grab sample showed elevated levels of Total Residual Chlorine (0.5 mg/L, Table 21). As a result, this sample was dechlorinated with sodium thiosulfate. A concurrent dechlorination laboratory control was also set up. Results for the dechlorinated control test showed only 30% survival, which makes these results for Site B suspect. The reduced survival may have been due to the effect of dechlorinating the sample.

All of the fifteen concurrent *Daphnia magna* reference toxicant survival endpoints were within the control chart limitations.

The DMC ambient control data met the 80% minimum survival acceptability criterion for all tests except for October 2001. The laboratory control did not meet the survival acceptability criterion for January and May.

Fathead Minnow (*Pimephales promelas*) 7-Day Acute Larval Survival

The *Pimephales promelas* 7-day acute larval survival results are presented in Table 2 and in Figures 2, 7, 12, and 17. Six tests showed a statistically significant ($p<0.05$) reduction in larval fathead minnow survival when compared to the DMC ambient control water. This reduced survival was consistently observed during four months: November 2001 (Site D), December 2001 (Sites C and D), November 2002 (Site C and F), and December 2002 (Site D).

The survival data for the *Pimephales promelas* larvae indicate an adverse effect for Sites C, D, and F between November and December of each year. Site D had the greatest effect in

total number of occurrences (3 events). All statistically significant tests occurred during the winter months, which is usually the wet season. Each concurrent *Pimephales promelas* reference toxicant survival endpoint was within the control chart limits.

Data for the DMC ambient control and the laboratory control met the minimum 80% acceptability criteria for all 15 sampling events.

Daphnia magna Short-Term Chronic Reproduction

The *Daphnia magna* short-term chronic reproduction results are presented in Table 3 and in Figures 3, 8, 13, and 18. Three tests showed statistically significant ($p<0.05$) reduced reproduction for February (Site B), June (Site F) and November 2002 (Site B). The November 2002 Site B reduction may have been the result of the dechlorination of the sample. This is supported by reduced reproduction in the concurrent dechlorinated laboratory control.

All of the concurrent *Daphnia magna* reference toxicant reproduction endpoints were within the control chart limitations.

The DMC ambient control data met the 10 neonates/surviving female minimum reproduction acceptability criterion in all fifteen tests. The laboratory control met the reproduction acceptability criterion in all but one of the fifteen tests (May, 2002).

Fathead Minnow (*Pimephales promelas*) 7-Day Chronic Larval Growth

The *Pimephales promelas* 7-day chronic larval growth results are presented in Table 4 and in Figures 4, 9, 14, and 19. A Statistically significant ($p<0.05$) reduced rate of growth was observed in five tests: December 2001 (Site C), August 2002 (Site B), November 2002 (Sites C), and December 2002 (Sites C and D). A significantly ($p<0.05$) increased rate of growth was observed for site F (November 2002) when compared to the DMC ambient control. Each concurrent *Pimephales promelas* reference toxicant growth endpoint was within the control chart limits. All data for the DMC ambient control and the laboratory control met the 0.25mg/surviving adult minimum growth acceptability criterion as shown in Table 4.

Freshwater Alga (*Selenastrum capricornutum*) 96-Hour Growth Test

The freshwater algal 96-hour growth test results are presented in Table 5 and in Figures 5, 10, 15, and 20. Seventeen tests produced statistically significant ($p<0.05$) reductions in algal growth. The reduced growth was observed during the November 2001 (Site B), December 2001 (Site B), January (Site B), February (Sites B, D and F), March (Sites B, C and D), April (Sites B and D), June (Site B, D and F), and October 2002 (Sites C, D and F) tests.

Site B had the highest number of statistically significant test results, 7, from November through April and again in June. These results are similar to previous years, wherein Site B had the highest number of statistically significant test results, usually during the winter months.

There are no results for August 2002 as the laboratory stock culture did not survive the 96-hour testing period.

All concurrent *S. capricornutum* reference toxicant growth endpoints were within the control chart limitations.

Both the DMC and Lab control failed to meet the minimum growth acceptability criterion during November 2001, December 2001, April 2002, May 2002 and December 2002. The DMC control also failed the minimum variance criterion of < 20 percent in December 2002. These results are summarized in Table 5.

Definitive Bioassay Testing

Definitive bioassay tests were conducted on with Site B water samples during all fifteen months of the study period (Table 6). The definitive bioassay used a dilution series of the site water at 12.5, 25, 50, 75, and 100 percent of the site water diluted with water from the DMC (ambient water). The results were compared to the DMC water. Laboratory control water was used as a second control for possible toxicity in the DMC water.

The definitive bioassay method allowed for the determination of the No Observed Effect Concentration (NOEC). The NOEC is a statistically derived calculation of the amount of the test water dilution needed to eliminate those adverse effects that are measured by these tests. For example, in January 2002, the NOEC was 25 (Table 6). This means that in order that a test endpoint not to differ statistically from the control, sample water must be a diluted to 25 percent with 75 percent of ambient water.

Results from the fifteen monthly tests for the study period (Table 6) showed that four samples did not exhibit toxicity (NOEC > 100%) at full-strength test water (October 2001, July 2002, October 2002, and December 2002), two samples had NOECs of 75 percent (November 2001 and September 2002), three samples had NOECs of fifty percent (December 2001, April 2002, and May 2002), two samples had NOECs of 25 percent (January 2002 and November 2002), and three samples had NOECs of 12.5 percent or less (February 2002, March 2002, and June 2002). The NOEC was not calculable for August 2002.

These data also can be expressed in toxicity units, where:

Toxicity Unit (TU) = 100/NOEC

In general, toxicity units are used to standardize the results of toxicity tests regardless of the statistical endpoint used. In the example given above for January 2002, the NOEC was 25, which is equivalent to four TU. A compilation of data for 30 months in which there was definitive testing of algae is listed in Table 6. Two months' results showed toxicity units of greater than sixteen (December 1999, September 2000). During these months, the Site B water would have had to have been diluted more than sixteen times to eliminate those toxic effects. Toxicity units were greater than or equal to eight in samples collected June 2000, February 2002, and March 2002; equal to 4 for two months and equal to 2 for three months. On the other hand, twelve of the thirty tests resulted in toxicity units equal to or less than one.

Water Chemistry

<u>Selenium</u>

The selenium data are presented in Table 11 and Figures 21a and 21b. Site B had the highest selenium concentrations for the entire water year, with the months of April, October 2002, November 2002 and December 2002 having the highest concentrations (ranging between 52-78 μg/L). The July and August 2002 sampling events had the lowest selenium concentrations, ranging from of 28 to 45 μg/L. Site D showed the same seasonal trends as Site B

although concentrations were 50-70% lower than Site B for the period October 2001 through March 2002. For the period beginning in April 2002 and continuing through August 2002, the selenium concentrations measured at Site D were similar to those observed from Site B.

<u>Sulfate</u>

Sulfate was not analyzed in water samples collected during the fifteen-month study period.

Other Water Chemistry

The laboratory water chemistry data are presented in Tables 12 through 21. All analyses were performed at the BES Laboratory, except for selenium.

The conductivity was higher for Site B water for all months except for the first sampling event in March and April 2002. Site C and F had the lowest conductivity (Table 12). The DO and pH of all sites were similar, with Site F showing the lowest pH on average (Tables 14 and 15). The Site B water is about two to three times greater in hardness than the other sites, exceeding 1000 mg/L (as $CaCO_3$) during October through December 2001, January and September through December 2002 (Table 18). Total suspended solids were generally higher in Site C and F water and lowest in Site B water. Suspended solids remain higher from March through October at Sites C, D and F (Table 13). No trend in alkalinity was observed. In January 2002 Sites D and F had elevated levels of alkalinity and in March Sites C and D had elevated levels (Table 17). The highest ammonia nitrogen concentration was observed in October 2001 at Site B (3.80 mg/L) (Table 20). The total chlorine concentration ranged from non-detectable to 2.50 mg/L. Site B had the highest chlorine concentration in August 2002 (2.50 mg/L) (Table 21).

Conclusions

A total of 180 laboratory toxicity tests (four sites, 15 months with three species) comparing the Site waters (B, C, D, and F) with the ambient control (Delta Mendota Canal) were conducted between October 2001 and December 2002 using three species short-term acute and chronic tests. Each set of tests included five toxicity endpoints (fish survival and growth, water flea survival and reproduction, and algae growth). Of these tests, 34 endpoints (Site B = 11, Site C = 7, Site D = 9, and Site F = 7) of the 300 possible (11.3 %) exhibited statistically significant reduced endpoints ($P<0.05$) compared to the ambient control tests.

Daphnia magna was the least sensitive of the species tested with 2 significant responses for reproduction and 3 for survival.

The freshwater alga was the most sensitive species tested. The algae exposed to Site B water exhibited reduced growth when compared to DMC ambient control water in 7 out of 15 months. As a whole, 17 of 56 tests demonstrated a significant reduction in algal growth. Definitive testing was initiated in November 1999 for Site B to evaluate the No Observed Effect Concentration (NOEC) for Site B test water when compared to ambient water. Of the 14 tests conducted during the fifteen month study period, 4 samples had NOECs greater than 100, 2 samples had NOECs at 75 percent (November 2001 and September 2002), 3 samples at 50 percent (December 2001, April and May 2002), 2 samples at 25 percent (January 2002 and November 2002), 1 sample at 12.5 percent (June 2002) and 2 samples (February and March

2002) had NOECs less than 12.5 percent, as shown Table12. The August results are not included, as the test was not valid.

The larval *Pimephales promelas* accounted for 12 statistically significant responses for survival and growth. The majority of these responses were during the winter months (November through January) at Sites C, D, and F.

All statistically significant events are summarized in the Tables 7 through 10.

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U.S. Environmental Protection Agency. 1994. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms. EPA-600-4-91-002. July 1994, Third Edition. Office of Research and Development.

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Table 1. Daphnid invertebrate (Daphnia magna) Short-term Acute Survival

Units	Site B Percent	Site C Percent	Site D Percent	Site F Percent	Ambient (DMC) Percent	Laboratory Control Percent
Oct-01	90	100	90	90	70**	90
Nov-01	100	89	90	100	80	90
Dec-01	90	100	90	90	100	100
Jan-02	100	90	80	100	100	67**
Feb-02	100	80	90	90	100	100
Mar-02	90	100	100	100	90	100
Apr-02	100	90	100	90	100	100
May-02	80	100	80	100	89	30**
Jun-02	100	90	90	90	100	90
Jul-02	90	100	100	100	100	100
Aug-02	100	90	100	60*	100	90
Sep-02	90	100	90	100	90	90
Oct-02	100	89	90	100	100	89
Nov-02	60*/***	100	100	100	100	100
Dec-02	100	100	100	90	100	90
Figure:	1	6	11	16		

Notes.	No statistics were computed between sampling dates.
*	Statistically significant event (P<0.05). Statistics were computed between all site means and the DMC ambient water sample.
**	DMC/Lab water failed to meet the survival (≥ 80%) acceptability criteria.
***	Sample was dechlorinated. Dechlorinated lab control was 30 percent survival This result is suspect

Table 2. Fathead Minnow (Pimephales promelas)7-Day Acute Larval Survival

Units:	Site B (Percent + Standard Deviation)	Site C (Percent + Standard Deviation)	Site D (Percent + Standard Deviation)	Site F (Percent + Standard Deviation)	Ambient (DMC) (Percent + Standard Deviation)	Laboratory Control (Percent + Standard Deviation)
Oct-01	100 + 0.0	98 + 5.0	100 + 0.0	100 + 0.0	100 + 0.0	100 + 0.0
Nov-01	98 + 5.0	83 + 28.7	60* + 21.60	88 + 25.0	100 + 0.0	100 + 0.0
Dec-01	98 + 5.0	55* + 33.2	68* + 5.0	90 + 8.2	98 + 5.2	100 + 0.0
Jan-02	83 + 15.0	95 + 5.8	98 + 5.0	100 + 0.0	100 + 0.0	98 + 5.0
Feb-02	93 + 5.0	90 + 11.5	93 + 5.8	95 + 5.8	93 + 5.0	100 + 0.0
Mar-02	98 + 5.0	90 + 0	98 + 5.0	80 + 14.1	88 + 12.6	98 + 5.0
Apr-02	93 + 5.0	93 + 5.0	85 + 10.0	95 + 5.8	95 + 5.8	98 + 5.0
May-02	98 + 5.0	95 + 5.8	95 + 10.0	90 + 11.5	85 + 17.3	88 + 18.9
Jun-02	98 + 5.0	100 + 0	100 + 0.0	95 + 5.8	95 + 5.8	100 + 0.0
Jul-02	100 + 0.0	95 + 5.8	98 + 5.0	93 + 5.0	90 + 14.1	100 + 0.0
Aug-02	85 + 10.0	88 + 5.0	95 + 10.0	90 + 8.2	95 + 10.0	98 + 5.0
Sep-02	100 + 0.0	98 + 5.0	98 + 5.0	95 + 5.8	95 + 5.8	93 + 9.6
Oct-02	93 + 5.0	98 + 5.0	100 + 0.0	93 + 9.6	98 + 5.0	100 + 0.0
Nov-02	98 + 5.0	55* + 26.5	83 + 17.1	65* + 28.9	100 + 0.0	100 + 0.0
Dec-02	100 + 0.0	88 + 0.1	78* + 0.1	98 + 0.1	98 + 5.0	100 + 0.0
Figure:	4	9	14	19		

Notes:	No statistics were computed between sampling dates.
*	Statistically significant event (P=0 05). Statistics were computed between all site means and the DMC ambient water sample.

Table 3. Daphnid invertebrate (Daphnia magna) Short-term Chronic Reproduction

Units:	Site B Number of Neonates per Female + Standard Deviation	Site C Number of Neonates per Female + Standard Deviation	Site D Number of Neonates per Female + Standard Deviation	Site F Number of Neonates per Female + Standard Deviation	Ambient (DMC) Number of Neonates per Female + Standard Deviation	Laboratory Control Number of Neonates per Female + Standard Deviation
Oct-01	39.50 + 16.11	39.10 + 8.49	29.80 + 18.03	35.30 + 13.34	21.10 + 15.55	31.70 + 12.34
Nov-01	27.40 + 4.81	28.22 + 13.72	34.20 + 7.22	33.40 + 7.31	25.40 + 10.01	29.60 + 11.42
Dec-01	41.30 + 16.20	45.90 + 11.21	43.30 + 18.40	42.40 + 19.25	45.10 + 10.04	36.70 + 13.61
Jan-02	29.40 + 7.46	29.30 + 12.51	23.60 + 14.71	30.50 + 3.81	30.10 + 4.43	11.89 + 9.47
Feb-02	42.80* + 4.42	37.70 + 20.51	42.00 + 15.37	40.60 + 18.47	47.40 + 7.03	32.40 + 14.62
Mar-02	47.20 + 17.89	47.70 + 11.24	49.80 + 20.94	45.80 + 10.01	54.50 + 27.09	50.20 + 18.46
Apr-02	56.20 + 13.32	43.40 + 18.24	59.80 + 12.02	49.30 + 18.78	49.50 + 6.85	47.33 + 11.84
May-02	26.40 + 16.72	36.50 + 8.62	30.70 + 17.56	37.20 + 9.37	27.89 + 14.69	2.90** + 4.73
Jun-02	40.00 + 11.69	36.10 + 19.79	43.10 + 20.22	24.30* + 13.98	45.30 + 11.34	28.60 + 19.94
Jul-02	28.30 + 17.83	29.70 + 15.28	34.56 + 13.85	29.60 + 15.38	33.10 + 5.30	29.10 + 14.69
Aug-02	40.80 + 13.16	26.60 + 13.40	34.10 + 16.19	20.40 + 22.46	25.60 + 15.21	22.90 + 14.72
Sep-02	24.40 + 17.08	28.00 + 9.20	28.70 + 12.93	31.10 + 14.38	23.70 + 13.45	23.70 + 13.45
Oct-02	40.40 + 17.40	30.22 + 22.44	29.60 + 17.99	27.90 + 9.36	29.90 + 12.24	21.11 + 14.02
Nov-02	7.90*/*** + 7.42	30.30 + 13.86	33.50 + 10.32	29.30 + 11.85	18.40 + 18.11	20.30 + 14.67
Dec-02	22.80 + 6.34	26.30 + 6.75	36.70 + 13.27	29.90 + 19.89	26.70 + 15.0	21.40 + 13.33
Figure	3	8	13	18		

Notes:	No statistics were computed between sampling dates
*	Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample.
**	DMC/Lab water failed to meet the reproduction ($\geq$ 10) acceptability criteria
***	Sample was dechlorinated. Dechlorinated lab control ws 30 percent survival. This result is suspect

Table 4. Fathead Minnow (Pimephales promelas) 7-Day Chronic Larval Growth

Units:	Site B (In Milligrams + Standard Deviation)	Site C (In Milligrams + Standard Deviation)	Site D (In Milligrams + Standard Deviation)	Site F (In Milligrams + Standard Deviation)	Ambient (DMC) (In Milligrams + Standard Deviation)	Laboratory Control (In Milligrams + Standard Deviation)
Oct-01	0.63 + 0.04	0.71 + 0.11	0.78 + 0.07	0.65 + 0.02	0.66 + 0.04	0.58 + 0.02
Nov-01	0.70 + 0.02	0.49 + 0.18	0.49 + 0.16	0.59 + 0.14	0.67 + 0.05	0.52 + 0.04
Dec-01	0.48 + 0.04	0.34* + 0.15	0.41 + 0.03	0.55 + 0.04	0.47 + 0.05	0.50 + 0.03
Jan-02	0.39 + 0.03	0.41 + 0.02	0.44 + 0.05	0.51 + 0.06	0.44 + 0.03	0.40 + 0.05
Feb-02	0.55 + 0.04	0.47 + 0.07	0.58 + 0.11	0.55 + 0.11	0.52 + 0.06	0.42 + 0.02
Mar-02	0.40 + 0.04	0.47 + 0.04	0.50 + 0.03	0.41 + 0.15	0.43 + 0.09	0.48 + 0.03
Apr-02	0.64 + 0.04	0.63 + 0.10	0.50 + 0.09	0.63 + 0.01	0.55 + 0.03	0.58 + 0.04
May-02	0.63 + 0.04	0.70 + 0.30	0.62 + 0.14	0.65 + 0.10	0.61 + 0.12	0.56 + 0.28
Jun-02	0.38 + 0.07	0.43 + 0.08	0.41 + 0.03	0.42 + 0.04	0.31 + 0.03	0.50 + 0.04
Jul-02	0.31 + 0.02	0.33 + 0.03	0.34 + 0.05	0.35 + 0.03	0.31 + 0.05	0.34 + 0.04
Aug-02	0.49* + 0.04	0.49 + 5.50	0.58 + 5.0	0.59 + 0.14	0.57 + 0.07	0.55 + 0.06
Sep-02	0.38 + 0.01	0.38 + 0.04	0.29 + 0.05	0.33 + 0.07	0.31 + 0.07	0.30 + 0.01
Oct-02	0.66 + 0.10	0.66 + 0.06	0.71 + 0.14	0.62 + 0.06	0.67 + 0.07	0.61 + 0.09
Nov-02	0.41 + 0.05	0.22* + 0.14	0.40 + 0.03	0.72* + 0.10	0.38 + 0.06	0.33 + 0.08
Dec-02	0.55 + 0.04	0.48* + 0.07	0.49* + 0.08	0.60 + 0.06	0.57 + 0.03	0.52 + 0.06
Figure	4	9	14	19		

Notes:	No statistics were computed between sampling dates.
*	Statistically significant event (P=0.05) Statistics were computed between all site means and the DMC ambient water sample.

Table 5. Freshwater Algae (Selenastrum capricornutum) 96-hour Growth Test

	Site B		Site C		Site D		Site F		Ambient (DMC)		Lab Control	
	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %	Cells cells/mL	Variance %
Oct-01	9.1	16.4	10.73	5.9	11.29	4.3	11.37	10.6	10.29	13.2	9.30	10.9
Nov-01	6.04*	17.2	11.14	17.2	11.03	24.8	9.98	15.2	9.21**	16.9	6.35**	6.1
Dec-01	7.48*	12.7	9.41	10.8	9.59	6.3	9.34	11.9	8.87**	11.0	9.08**	7.5
Jan-02	6.62*	12.7	19.21	4.3	17.35	10.3	24.67	10.8	15.14	24.7	10.08	16.4
Feb-02	8.7*	11.3	17.28	27.7	14.93*	8.4	12.68*	11.9	18.21	12.7	12.58	7.4
Mar-02	8.7*	10.7	14.24*	10.2	12.88*	13.2	18.24	11.8	17.77	18.3	13.50	10.9
Apr-02	1.44*	14.4	6.96	6.9	4.37*	15.2	6.56	13.8	5.80**	13.5	6.90**	3.2
May-02	4.77	28.1	7.93	21.1	6.13	8.2	6.26	9.7	7.10**	7.0	3.78**	9.2
Jun-02	6.39*	15.8	9.47	27.0	7.65*	21.3	6.8*	24.0	11.73	8.2	10.21	16.3
Jul-02	5.98	28.5	10.16	8.4	10.34	24.2	10.51	15.0	6.77	11.4	8.71	9.6
Aug-02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sep-02	10.93	2.3	8.15	0.9	7.40	1.8	7.60	2.6	11.90	1.2	11.97	
Oct-02	8.87	1.5	5.94*	1.0	6.37*	0.7	6.43*	4.2	7.84	4.0	9.53	11.3
Nov-02	10.76	1.3	15.71	0.4	11.19	4.3	10.81	2.0	15.66	1.0	14.20	0.8
Dec-02	7.34	30.9	9.67	21.0	9.99	15.3	6.84	23.4	2.44***	25.3	7.67**	13.6

Figure	5		10		15		20					

Notes: Cell count values expressed as the exponent 10^5.
Selenate added
No statistics were computed between sampling dates.

*	Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample.
**	DMC/Control water failed to meet the growth ($\geq 1 \times 10^6$) acceptability criteria.
***	DMC/Control water failed to meet the variance ($\leq 20\%$) acceptability criteria.
NA	Not available

Table 6. Statistical Analysis of Growth Endpoints for Algae at Site B

Test Month	IC 50	IC 25	NOEC	LOEC	Toxic Units
Feb-1998	79.16	46.85	>100	>100	<1
Mar-1998	83.62	58.83	50.00	100.00	2
Apr-1998	>100	31.67	25.00	50.00	4
Oct-1999	NA	NA	NA	NA	NA
Nov-1999	>100	87 45	50.00	100.00	2
Dec-1999	>100	54.44	<6 25	6 25	>16
Jan-2000	72.98	38.58	25 00	50.00	4
Feb-2000	>100	36.68	25 00	50.00	4
Mar-2000	>100	100.00	>100	>100	<1
Apr-2000	>100	>100	>100	>100	<1
May-2000	>100	>100	>100	>100	<1
Jun-2000	>100	>100	12.50	25.00	8
Jul-2000	>100	>100	>100	>100	<1
Aug-2000	>100	>100	>100	>100	<1
Sep-2000	NA	NA	<6.25	6.25	>16
Oct-2001	>100	>100	>100	>100	<1
Nov-2001	>100	85.95	75.00	100.00	1
Dec-2001	>100	73.72	50.00	75.00	2
Jan-2002	81.91	48 92	25.00	50.00	4
Feb-2002	95 22	19.71	<12.5	12.50	>8
Mar-2002	98.48	56.23	<12.5	12.50	>8
Apr-2002	78.73	56 82	50.00	75.00	2
May-2002	>100	69.94	50.00	75.00	2
Jun-2002	81.13	32.71	12.50	25.00	8
Jul-2002	>100	>100	>100	>100	<1
Aug-2002	NA	NA	NA	NA	NA
Sep-2002	>100	>100	75.00	100.00	1
Oct-2002	>100	>100	>100	>100	<1
Nov-2002	>100	48.34	25.00	50.00	4
Dec-2002	>100	>100	>100	>100	<1

Data Source: Block Environmental Services

Notes:
NA - Not available

Table 7. Summary of Statistically Significant Results - Site B

Table 7a. ***Daphnia magna*** **Short-term Acute Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998															
1999															
2000															
2001								•	•		•				
2002+														•	

Table 7b. ***Pimephales promelas*** **7-day Acute Larval Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998															
1999															
2000															
2001															
2002+															

Table 7c. ***Daphnia magna*** **Short-term Chronic Reproduction**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998				•											
1999	•														
2000															
2001								•	•		•				
2002+					•									•	

Table 7d. ***Pimephales promelas*** **7-day Chronic Larval Growth**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997					•										
1998	•	•													
1999															
2000															
2001					•				•						
2002+											•				

Tabls 7e. **Freshwater Algae (Selenastrum capricornutum) 96-hour Growth Test**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			•		•	•	•		•			•			
1998	•			•	•	•		•	•			•			
1999	•	•	•	•	•						•				
2000		•	•	•	•										
2001			•		•			•	•		•	•			
2002+		•	•	•	•	•	•		•		na				

• Statistically significant event ($p<0.05$) Statistics were computed between all site means and the DMC ambient water sample

Table 8. Summary of Statistically Significant Results - Site C

Table 8a. ***Daphnia magna*** **Short-term Acute Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998															
1999															
2000															
2001				•					•						
2002+															

Table 8b. ***Pimephales promelas*** **7-day Acute Larval Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			•		•										
1998		•	•	•	•	•									
1999	•	•	•												
2000		•	•	•											
2001	•	•	•												
2002+			•											•	

Table 8c. ***Daphnia magna*** **Short-term Chronic Reproduction**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998															
1999															
2000															
2001									•						
2002+															

Table 8d. ***Pimephales promelas*** **7-day Chronic Larval Growth**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997										•					
1998	•	•	•	•	•	•					•				
1999	•	•													
2000		•	•	•											
2001	•	•	•		•										
2002+			•											•	•

Table 8e. **Freshwater Algae (*Selenastrum capricornutum*) 96-hour Growth Test**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997					•		•	•							
1998															
1999						•	•								
2000															
2001									•						
2002+						•					na		•		

• Statistically significant event (p<0.05). Statistics were computed between all site means and the DMC ambient water sample

Table 9. Summary of Statistically Significant Results - Site D

Table 9a. ***Daphnia magna*** **Short-term Acute Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998															
1999															
2000															
2001	•								•	•	•				
2002+															

Table 9b. ***Pimephales promelas*** **7-day Acute Larval Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			•												
1998			•	•	•	•									
1999		•		•											
2000		•	•	•	•										
2001		•													
2002+		•	•												•

Table 9c. ***Daphnia magna*** **Short-term Chronic Reproduction**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998				•											
1999	•														
2000															
2001									•		•				
2002+															

Table 9d. ***Pimephales promelas*** **7-day Chronic Larval Growth**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	•														
1998	•			•	•	•									
1999		•													
2000		•													
2001	•	•	•												
2002+															•

Table 9e. **Freshwater Algae (*Selenastrum capricornutum*) 96-hour Growth Test**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			•		•	•		•							
1998												•			
1999		•			•										
2000	•	•													
2001									•		•				
2002+					•	•	•		•		na		•		

• Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample

Table 10. Summary of Statistically Significant Results - Site F

Table 10a. ***Daphnia magna*** **Short-term Acute Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998															
1999															
2000															
2001															
2002+											•				

Table 10b. ***Pimephales promelas*** **7-day Acute Larval Survival**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998	•				•	•			•						
1999		•		•											
2000	•	•	•		•										
2001		•													
2002+														•	

Table 10c. ***Daphnia magna*** **Short-term Chronic Reproduction**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998				•	•										
1999															
2000															
2001															
2002+									•						

Table 10d. ***Pimephales promelas*** **7-day Chronic Larval Growth**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997															
1998	•	•			•	•			•						
1999		•		•							•				
2000		•	•		•										
2001		•													
2002+														•	

Table 10e. **Freshwater Algae (*Selenastrum capricornutum*) 96-hour Growth Test**

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997						•	•	•							
1998															
1999			•	•	•										
2000					•										
2001					•		•		•						
2002+					•				•		na		•		

• Statistically significant event ($p<0.05$). Statistics were computed between all site means and the DMC ambient water sample

Table 11. Selenium (µg/L) as Measured by the Bureau of Reclamation

SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
22-Oct-01	53	<0 4	7 3	<0 4	<0.4
24-Oct-01	51	0 4	7 8	<0 4	<0 4
26-Oct-01	30	<0 4	5.2	<0 4	<0 4
26-Nov-01	44	<0.4	6 0	<0 4	<0 4
28-Nov-01	47	<0.4	5 2	<0 4	<0 4
30-Nov-01	49	<0 4	6 2	<0 4	0 5
10-Dec-01	55	<0 4	8 2	<0 4	<0 4
12-Dec-01	45	<0 4	7 4	<0 4	<0.4
14-Dec-01	47	<0 4	8 4	<0 4	<0 4
28-Jan-02	61	<0 4	13 0	<0 4	<0 4
30-Jan-02	56	<0 4	14 0	0 8	<0 4
1-Feb-02	66	<0 4	13 0	0 5	<0 4
18-Feb-02	61	0 7	20 0	0.9	1 3
20-Feb-02	65	0.7	20 0	1 0	1 2
22-Feb-02	70	0.8	22 0	0 9	1 0
25-Mar-02	78	<0 4	24 0	0 4	1 7
27-Mar-02	77	<0 4	27 0	0 6	<0 4
29-Mar-02	81	<0 4	26 0	<0.4	<0 4
22-Apr-02	62	0 6	52 0	0 7	0 4
24-Apr-02	78	0 8	37 0	0.8	0 4
26-Apr-02	70	0 7	48 0	0 7	<0.4
20-May-02	52	0 7	38 0	0 5	<0 4
22-May-02	34	0 6	25 0	0 5	<0 4
24-May-02	46	0 8	27 0	0.5	<0 4
24-Jun-02	48	0.9	29 0	0 5	<0 4
26-Jun-02	48	0 8	38 0	0.7	<0.4
28-Jun-02	52	0 5	50 0	0 7	0 5
22-Jul-02	30	0 5	22 0	0 5	0 5
24-Jul-02	32	0 8	17.0	0 4	<0 4
26-Jul-02	32	0 9	20 0	<0 4	<0 4
19-Aug-02	28	0 7	21 0	0 5	<0 4
21-Aug-02	34	0 7	26 0	0 6	<0 4
23-Aug-02	45	0 7	26 0	0 5	<0 4
23-Sep-02	48	0 5	15 0	0 5	<0.4
25-Sep-02	44	0 5	11 0	<0 4	<0 4
27-Sep-02	48	<0 4	18 0	0 4	<0 4
14-Oct-02	75	0 4	15.0	<0 4	<0 4
16-Oct-02	52	<0 4	7 0	<0.4	<0 4
18-Oct-02	57	<0.4	10 0	<0 4	<0 4
18-Nov-02	55	0 5	7 6	<0 4	<0 4
20-Nov-02	67	0.4	7 6	0 5	<0.4
22-Nov-02	68	0 4	6 5	<0 4	<0 4
16-Dec-02	78	0 4	12 0	0 8	0 6
17-Dec-02	72	<0 4	8 0	0 8	0 6
20-Dec-02	70	<0 4	10 0	0 7	1 0

Data Source Analysis conducted by SDSU Olson Laboratory for the US Bureau of Reclamation

Table 12: Conductivity (µS) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	22-Oct-01	3,241	900	1,274	1,200	484
Oct-01	24-Oct-01	2,916	951	1,274	1,030	467
	26-Oct-01	2,965	1,125	1,189	1,219	497
	26-Nov-01	2,906	1,104	1,302	1,098	451
Nov-01	28-Nov-01	2,758	1,042	1,263	1,024	373
	30-Nov-01	2,820	1,030	1,268	920	531
	10-Dec-01	2,860	1,132	1,430	1,001	381
Dec-01	12-Dec-01	2,930	1,115	1,456	1,009	402
	14-Dec-01	2,929	1,321	1,645	1,278	381
	28-Jan-02	476	233	195	289	290
Jan-02	30-Jan-02	3,462	3,330	2,076	1,502	296
	1-Feb-02	4,928	1,547	3,005	1,293	358
	18-Feb-02	4,458	2,323	3,080	1,570	960
Feb-02	20-Feb-02	3,438	2,351	3,188	1,033	870
	22-Feb-02	4,763	2,265	3,170	772	473
	25-Mar-02	3,237	2,880	3,650	1,272	760
Mar-02	27-Mar-02	4,025	2,730	3,647	385	388
	29-Mar-02	3,658	2,678	3,480	NA	238
	22-Apr-02	2,884	1,686	1,062	3,116	361
Apr-02	24-Apr-02	3,460	987	2,277	1,174	315
	26-Apr-02	3,520	1,216	2,072	1,157	268
	20-May-02	3,396	1,507	1,315	756	8
May-02	22-May-02	2,664	1,192	2,441	714	8
	24-May-02	3,285	1,141	2,385	866	8
	24-Jun-02	3,710	960	2,791	978	283
Jun-02	26-Jun-02	3,456	1,058	2,720	831	265
	28-Jun-02	3,409	1,927	3,221	833	239
	22-Jul-02	2,895	653	2,104	753	279
Jul-02	24-Jul-02	3,127	758	1,914	790	297
	26-Jul-02	3,313	822	2,320	822	274
	19-Aug-02	2,275	686	1,620	697	346
Aug-02	21-Aug-02	2,579	790	1,935	849	400
	23-Aug-02	2,436	734	1,901	821	359
	23-Sep-02	3,183	821	1,621	1,013	561
Sep-02	25-Sep-02	2,727	616	1,208	971	437
	27-Sep-02	2,985	759	1,591	983	532
	14-Oct-02	4,225	888	1,776	1,057	461
Oct-02	16-Oct-02	3,212	740	1,018	1,137	442
	18-Oct-02	3,215	756	1,036	1,073	445
	18-Nov-02	2,496	1,210	1,216	844	426
Nov-02	20-Nov-02	2,871	1,021	1,246	921	360
	22-Nov-02	2,589	1,232	1,239	893	378
	16-Dec-02	2,823	1,084	1,426	730	377
Dec-02	17-Dec-02	3,408	1,238	1,540	1,000	507
	20-Dec-02	3,059	1,091	1,413	934	637

NA-Not Available

Table 13: Total Suspended Solids (mg/L) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	20-Oct-01	44	16	11	52	4
Oct-01	22-Oct-01	54	28	21	65	11
	24-Oct-01	55	8	32	126	5
	26-Nov-01	45	39	20	57	11
Nov-01	28-Nov-01	62	21	28	NA	16
	30-Nov-01	57	29	53	101	23
	10-Dec-01	32	18	15	49	74
Dec-01	12-Dec-01	40	8	13	48	28
	14-Dec-01	58	23	43	57	12
	28-Jan-02	55	23	26	74	52
Jan-02	30-Jan-02	58	22	26	43	40
	1-Feb-02	74	19	28	101	29
	18-Feb-02	52	36	73	101	29
Feb-02	20-Feb-02	34	48	40	81	40
	22-Feb-02	74	54	47	120	50
	25-Mar-02	40	94	56	46	16
Mar-02	27-Mar-02	38	108	80	75	27
	29-Mar-02	61	163	118	64	34
	22-Apr-02	59	45	85	129	129
Apr-02	24-Apr-02	45	82	82	104	104
	26-Apr-02	31	127	93	198	198
	20-May-02	42	52	48	139	139
May-02	22-May-02	47	79	84	138	138
	24-May-02	43	55	54	148	148
	24-Jun-02	52	36	46	119	119
Jun-02	26-Jun-02	69	81	82	168	168
	28-Jun-02	57	34	47	159	159
	22-Jul-02	44	172	139	181	181
Jul-02	24-Jul-02	55	167	147	210	210
	26-Jul-02	91	254	NA	153	153
	19-Aug-02	NA	NA	NA	NA	NA
Aug-02	21-Aug-02	58	135	86	146	146
	23-Aug-02	61	79	71	155	155
	23-Sep-02	55	76	72	38	38
Sep-02	25-Sep-02	66	52	69	168	168
	27-Sep-02	70	111	69	148	148
	14-Oct-02	45	69	71	130	14
Oct-02	16-Oct-02	59	93	67	197	29
	18-Oct-02	56	44	58	72	24
	18-Nov-02	55	23	35	60	12
Nov-02	20-Nov-02	82	26	34	94	17
	22-Nov-02	67	43	43	119	24
	16-Dec-02	68	69	82	69	26
Dec-02	17-Dec-02	63	23	24	85	54
	20-Dec-02	80	36	41	58	18

NA-Not Available

Table 14: Dissolved Oxygen (mg/L) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Oct-01	22-Oct-01	12.4	7.1	7.1	9.0	9.4
	24-Oct-01	11.5	10.3	8.4	8.4	9.0
	26-Oct-01	12.1	8.2	8.5	8.7	9.8
Nov-01	26-Nov-01	10.7	10.7	10.4	10.2	10.1
	28-Nov-01	10.8	11.5	11.3	11.0	11.2
	30-Nov-01	11.4	11.0	11.0	10.9	10.8
Dec-01	10-Dec-01	11.6	11.1	11.0	10.7	10.6
	12-Dec-01	11.5	10.5	10.9	10.6	10.6
	14-Dec-01	10.7	9.8	9.5	8.7	9.5
Jan-02	28-Jan-02	7.9	10.2	9.2	8.7	11.3
	30-Jan-02	12.3	12.7	12.1	11.5	11.5
	1-Feb-02	11.7	10.1	11.5	11.2	10.6
Feb-02	18-Feb-02	10.5	9.7	10.2	8.6	11.0
	20-Feb-02	12.0	9.9	10.7	9.4	10.4
	22-Feb-02	11.9	9.2	9.8	10.3	9.4
Mar-02	25-Mar-02	12.6	11.7	10.9	11.2	10.0
	27-Mar-02	12.1	10.6	10.4	10.7	10.5
	29-Mar-02	10.5	7.1	8.1	NA	8.6
Apr-02	22-Apr-02	11.6	9.9	8.0	10.6	10.1
	24-Apr-02	12.5	10.6	10.4	9.0	10.8
	26-Apr-02	10.8	9.2	10.0	9.0	10.8
May-02	20-May-02	10.5	10.5	10.1	9.6	9.4
	22-May-02	11.7	9.8	10.1	8.0	10.2
	24-May-02	11.0	8.6	9.3	7.7	9.7
Jun-02	24-Jun-02	12.0	9.1	9.5	7.5	8.6
	26-Jun-02	11.3	10.7	9.9	7.7	8.3
	28-Jun-02	11.6	10.0	10.4	7.8	9.4
Jul-02	22-Jul-02	10.7	10.2	9.6	9.4	9.0
	24-Jul-02	10.3	8.4	8.6	7.4	7.9
	26-Jul-02	9.6	7.8	8.0	7.0	7.7
Aug-02	19-Aug-02	11.2	9.2	9.1	9.2	8.5
	21-Aug-02	10.3	8.5	9.3	7.9	9.1
	23-Aug-02	10.5	9.0	9.0	8.8	8.8
Sep-02	23-Sep-02	9.8	6.0	6.7	8.4	8.3
	25-Sep-02	6.8	6.5	6.3	7.4	7.9
	27-Sep-02	8.5	6.6	7.5	8.5	8.4
Oct-02	14-Oct-02	10.4	7.0	7.6	8.9	8.8
	16-Oct-02	11.3	8.5	8.0	8.5	8.7
	18-Oct-02	10.6	8.6	7.9	8.6	8.7
Nov-02	18-Nov-02	12.0	7.9	8.5	8.9	9.6
	20-Nov-02	12.2	7.8	8.1	9.2	9.5
	22-Nov-02	11.8	7.8	8.3	9.0	9.2
Dec-02	16-Dec-02	10.4	9.7	9.9	9.5	9.9
	17-Dec-02	11.5	9.8	9.8	10.3	10.8
	20-Dec-02	11.0	10.0	10.4	9.7	10.3

NA- Not Available

Table 15: pH of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION Site B	Site C	Site D	Site F	Delta-Mendota Canal
Oct-01	22-Oct-01	8.2	7.7	7.7	7.7	7.8
	24-Oct-01	8.1	7.8	7.8	7.8	7.9
	26-Oct-01	8.3	7.8	7.9	7.8	8.0
Nov-01	26-Nov-01	7.5	7.7	7.7	7.7	7.8
	28-Nov-01	7.9	8.0	8.0	8.0	8.1
	30-Nov-01	8.2	8.3	8.3	8.2	8.3
Dec-01	10-Dec-01	8.0	8.0	7.9	7.6	7.7
	12-Dec-01	7.9	7.9	7.9	7.6	7.7
	14-Dec-01	8.0	7.9	7.9	7.5	7.6
Jan-02	28-Jan-02	8.1	7.9	8.1	7.8	8.5
	30-Jan-02	7.9	8.0	7.9	7.7	7.8
	1-Feb-02	7.7	7.9	7.7	7.8	7.8
Feb-02	18-Feb-02	8.0	7.8	7.9	7.4	7.6
	20-Feb-02	7.9	8.0	8.0	7.8	7.9
	22-Feb-02	7.9	7.8	8.0	7.9	7.8
Mar-02	25-Mar-02	8.5	8.3	8.2	7.5	7.8
	27-Mar-02	8.5	8.2	8.2	7.9	8.1
	29-Mar-02	8.1	8.2	8.2	NA	6.5
Apr-02	22-Apr-02	8.2	7.9	7.8	8.2	7.9
	24-Apr-02	8.5	8.0	8.2	7.7	7.9
	26-Apr-02	8.3	7.8	8.1	7.6	8.0
May-02	20-May-02	8.3	8.0	8.1	7.8	7.9
	22-May-02	8.4	7.8	8.1	7.6	7.6
	24-May-02	8.1	8.1	8.3	7.9	8.0
Jun-02	24-Jun-02	8.5	8.4	8.4	7.9	8.0
	26-Jun-02	8.4	8.0	8.4	7.8	7.9
	28-Jun-02	8.4	8.2	8.5	7.8	7.9
Jul-02	22-Jul-02	8.2	7.8	8.3	7.7	7.8
	24-Jul-02	8.3	7.8	8.2	7.6	7.7
	26-Jul-02	8.3	7.9	8.3	7.5	7.7
Aug-02	19-Aug-02	8.4	8.0	8.3	7.7	7.7
	21-Aug-02	8.2	7.8	8.2	7.7	7.6
	23-Aug-02	8.3	8.0	8.2	7.7	7.6
Sep-02	23-Sep-02	8.3	7.4	7.5	7.5	7.2
	25-Sep-02	7.8	7.7	7.6	7.6	7.8
	27-Sep-02	8.0	7.9	7.8	7.5	7.5
Oct-02	14-Oct-02	8.8	7.3	7.8	7.6	7.4
	16-Oct-02	9.1	8.0	8.0	7.9	8.1
	18-Oct-02	9.0	8.0	7.9	7.8	8.0
Nov-02	18-Nov-02	8.3	7.8	7.8	7.6	7.5
	20-Nov-02	8.3	7.7	7.7	7.6	7.6
	22-Nov-02	8.3	7.7	7.7	7.6	7.7
Dec-02	16-Dec-02	8.0	8.0	8.0	7.4	8.0
	17-Dec-02	7.9	7.6	7.4	7.5	7.4
	20-Dec-02	7.9	8.0	8.0	7.4	8.0

NA-Not Available

Table 16: Salinity (ppt) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Oct-01	22-Oct-01	2.4	0.7	0.9	0.9	0.3
	24-Oct-01	2.4	0.8	1.0	0.8	0.4
	26-Oct-01	2.1	0.8	1.0	0.9	0.3
Nov-01	26-Nov-01	2.2	0.8	1.0	0.8	0.3
	28-Nov-01	2.2	0.9	1.0	0.8	0.3
	30-Nov-01	2.3	0.8	1.0	0.7	0.4
Dec-01	10-Dec-01	2.2	0.8	1.1	0.7	0.3
	12-Dec-01	2.2	0.8	1.1	0.7	0.3
	12/14/200	2.1	1.0	1.2	1.0	0.3
Jan-02	28-Jan-02	2.2	0.7	1.5	0.1	0.1
	30-Jan-02	2.7	2.6	1.6	1.1	0.2
	1-Feb-02	2.7	1.2	1.6	0.9	0.1
Feb-02	18-Feb-02	2.4	1.2	0.8	0.8	0.5
	20-Feb-02	2.7	1.2	1.3	0.7	0.4
	22-Feb-02	2.7	0.7	1.7	0.4	0.8
Mar-02	25-Mar-02	2.5	1.5	1.5	0.9	0.5
	27-Mar-02	2.8	1.4	1.9	0.2	0.2
	29-Mar-02	2.5	1.4	1.8	NA	0.1
Apr-02	22-Apr-02	1.7	1.2	0.7	2.3	0.2
	24-Apr-02	2.8	0.8	1.8	0.9	0.2
	26-Apr-02	2.7	0.9	2.1	0.9	0.2
May-02	20-May-02	2.6	1.1	2.3	0.6	0.3
	22-May-02	2.1	0.9	1.8	0.5	0.3
	24-May-02	2.1	0.7	1.5	0.5	2.0
Jun-02	24-Jun-02	2.1	0.5	1.6	0.5	0.1
	26-Jun-02	2.0	0.7	1.9	0.5	0.1
	28-Jun-02	2.3	1.4	2.3	0.6	0.2
Jul-02	22-Jul-02	2.0	0.3	1.4	0.5	0.2
	24-Jul-02	1.9	0.5	1.2	0.5	0.2
	26-Jul-02	2.1	0.5	1.5	0.5	0.2
Aug-02	19-Aug-02	2.0	0.6	1.4	0.6	0.3
	21-Aug-02	1.8	0.6	1.4	0.6	0.3
	23-Aug-02	1.8	0.6	1.4	0.6	0.3
Sep-02	23-Sep-02	2.0	0.5	1.0	0.6	0.3
	25-Sep-02	2.3	0.5	1.0	0.7	0.3
	27-Sep-02	2.1	0.5	1.0	0.7	0.3
Oct-02	14-Oct-02	3.0	0.6	1.2	0.7	0.3
	16-Oct-02	2.3	0.5	0.7	0.7	0.3
	18-Oct-02	2.4	0.5	0.9	0.7	0.3
Nov-02	18-Nov-02	2.1	1.0	1.0	0.7	0.3
	20-Nov-02	2.5	0.8	1.0	0.7	0.3
	22-Nov-02	2.3	0.9	1.0	0.7	0.3
Dec-02	16-Dec-02	2.5	0.9	1.2	0.6	0.3
	17-Dec-02	2.5	0.8	1.1	0.7	0.3
	20-Dec-02	2.5	0.9	1.1	0.7	0.5

NA-Not Available

Table 17: Alkalinity (as mg/L CaCO3) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	20-Oct-01	138	218	224	202	120
Oct-01	22-Oct-01	188	256	222	220	114
	24-Oct-01	198	250	234	212	114
	26-Nov-01	206	226	202	210	80
Nov-01	28-Nov-01	240	110	224	194	114
	30-Nov-01	200	230	220	170	128
	10-Dec-01	220	240	246	194	130
Dec-01	12-Dec-01	200	230	240	342	120
	14-Dec-01	170	220	498	406	120
	28-Jan-02	232	260	214	68	94
Jan-02	30-Jan-02	192	198	280	226	86
	1-Feb-02	208	280	308	194	114
	18-Feb-02	160	270	240	160	130
Feb-02	20-Feb-02	200	300	276	180	130
	22-Feb-02	160	280	260	200	120
	25-Mar-02	202	350	300	220	140
Mar-02	27-Mar-02	180	330	220	100	90
	29-Mar-02	140	360	270	NA	88
	22-Apr-02	110	260	140	160	100
Apr-02	24-Apr-02	190	170	160	184	100
	26-Apr-02	182	220	200	200	124
	20-May-02	140	220	200	140	90
May-02	22-May-02	160	200	180	150	110
	24-May-02	170	170	170	160	140
	24-Jun-02	150	140	150	150	100
Jun-02	26-Jun-02	140	160	150	160	90
	28-Jun-02	140	220	140	160	80
	22-Jul-02	128	128	124	130	66
Jul-02	24-Jul-02	114	136	128	130	68
	26-Jul-02	110	130	126	124	64
	19-Aug-02	154	136	146	126	66
Aug-02	21-Aug-02	152	148	146	140	70
	23-Aug-02	178	150	160	150	76
	23-Sep-02	130	150	150	146	80
Sep-02	25-Sep-02	130	150	140	160	90
	27-Sep-02	140	170	170	160	80
	14-Oct-02	100	180	158	152	80
Oct-02	16-Oct-02	112	150	138	158	64
	18-Oct-02	136	182	156	154	96
	18-Nov-02	184	228	216	160	88
Nov-02	20-Nov-02	186	234	228	174	76
	22-Nov-02	192	230	226	168	78
	16-Dec-02	180	216	222	130	86
Dec-02	17-Dec-02	178	210	206	146	84
	20-Dec-02	182	212	206	144	120

NA-Not Available

Table 18: Hardness (as mg/L CaCO3) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
Oct-01	20-Oct-01	1,082	94	396	332	174
	22-Oct-01	1,102	140	200	310	148
	24-Oct-01	1,010	352	452	364	204
Nov-01	26-Nov-01	994	364	416	208	172
	28-Nov-01	1,050	304	304	342	190
	30-Nov-01	1,230	400	460	370	200
Dec-01	10-Dec-01	1,088	362	470	308	164
	12-Dec-01	846	525	490	360	182
	14-Dec-01	1,058	332	524	428	152
Jan-02	28-Jan-02	1,000	240	600	140	120
	30-Jan-02	1,266	1,230	490	444	148
	1-Feb-02	1,248	496	304	396	162
Feb-02	18-Feb-02	201	510	650	360	240
	20-Feb-02	220	240	540	300	200
	22-Feb-02	200	460	680	360	204
Mar-02	25-Mar-02	700	170	750	330	244
	27-Mar-02	300	280	400	180	190
	29-Mar-02	240	400	600	NA	240
Apr-02	22-Apr-02	200	400	350	220	160
	24-Apr-02	200	400	400	260	150
	26-Apr-02	250	230	370	160	150
May-02	20-May-02	180	360	600	200	400
	22-May-02	200	330	400	400	500
	24-May-02	600	260	600	200	150
Jun-02	24-Jun-02	920	210	300	204	90
	26-Jun-02	900	400	250	260	110
	28-Jun-02	900	600	250	250	100
Jul-02	22-Jul-02	800	194	604	198	100
	24-Jul-02	804	196	490	216	84
	26-Jul-02	852	210	592	194	82
Aug-02	19-Aug-02	736	202	568	206	88
	21-Aug-02	760	212	602	224	92
	23-Aug-02	920	164	390	220	74
Sep-02	23-Sep-02	816	190	388	240	130
	25-Sep-02	220	120	400	240	110
	27-Sep-02	>1000	210	500	240	110
Oct-02	14-Oct-02	>1000	240	460	240	100
	16-Oct-02	920	190	266	260	114
	18-Oct-02	860	220	350	220	106
Nov-02	18-Nov-02	840	296	366	254	116
	20-Nov-02	>1000	294	372	264	98
	22-Nov-02	>1000	294	374	252	98
Dec-02	16-Dec-02	>1000	308	472	198	116
	17-Dec-02	>1000	262	392	464	128
	20-Dec-02	>1000	292	406	256	198

NA-Not Available

Table 19: Temperature (^{0}c) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	20-Oct-01	2.5	2.5	2.5	2.5	2.0
Oct-01	22-Oct-01	6.0	6.0	6.0	6.0	6.0
	24-Oct-01	7.5	4.9	5.2	4.8	4.8
	26-Nov-01	3.8	3.8	3.6	3.5	3.3
Nov-01	28-Nov-01	3.8	3.8	3.8	3.8	3.8
	30-Nov-01	3.8	3.5	3.4	3.4	3.4
	10-Dec-01	3.0	3.0	3.0	3.0	3.0
Dec-01	12-Dec-01	8.5	8.5	8.5	8.5	8.5
	14-Dec-01	2.9	2.6	3.8	2.4	3.7
	28-Jan-02	4.2	5.0	4.1	4.3	4.0
Jan-02	30-Jan-02	3.4	3.2	3.8	3.4	5.2
	1-Feb-02	2.8	8.0	3.7	4.7	3.7
	18-Feb-02	2.7	12.9	2.7	2.7	3.9
Feb-02	20-Feb-02	3.8	2.7	4.6	4.1	6.9
	22-Feb-02	4.3	4.7	9.7	5.9	8.3
	25-Mar-02	9.0	3.0	3.8	14.0	7.0
Mar-02	27-Mar-02	14.2	9.8	4.7	8.0	3.8
	29-Mar-02	3.0	7.9	9.0	NA	5.0
	22-Apr-02	8.0	8.0	8.0	8.0	8.0
Apr-02	24-Apr-02	4.0	4.0	4.0	4.0	4.0
	26-Apr-02	4.0	3.5	3.5	3.1	5.0
	20-May-02	8.1	7.7	8.6	7.2	7.6
May-02	22-May-02	3.0	3.5	4.0	5.1	5.0
	24-May-02	15.9	15.4	15.1	15.3	18.1
	24-Jun-02	20.7	20.1	20.8	19.7	21.2
Jun-02	26-Jun-02	9.5	9.5	9.5	9.5	9.5
	28-Jun-02	12.5	12.5	12.5	12.5	12.5
	22-Jul-02	8.0	8.0	8.0	8.0	8.0
Jul-02	24-Jul-02	6.0	5.8	6.0	6.5	13.5
	26-Jul-02	16.0	16.5	16.0	16.5	17.0
	19-Aug-02	6.0	6.0	6.0	6.0	6.0
Aug-02	21-Aug-02	9.5	9.5	9.5	9.5	9.5
	23-Aug-02	4.0	4.0	4.0	4.0	4.0
	23-Sep-02	7.5	3.5	4.5	8.0	4.5
Sep-02	25-Sep-02	5.2	5.2	5.2	5.2	5.2
	27-Sep-02	4.5	4.5	4.5	4.5	4.5
	14-Oct-02	0.7	1.0	0.7	5.0	1.0
Oct-02	16-Oct-02	3.0	3.0	3.0	3.0	3.0
	18-Oct-02	4.0	4.0	4.0	4.0	4.0
	18-Nov-02	2.0	1.5	1.0	1.0	6.0
Nov-02	20-Nov-02	2.5	2.5	2.5	2.5	2.5
	22-Nov-02	4.6	4.6	4.6	4.6	4.6
	16-Dec-02	1.0	1.0	1.0	4.0	1.0
Dec-02	17-Dec-02	1.5	2.0	1.5	2.5	2.0
	20-Dec-02	1.0	0.5	0.5	4.0	0.8

NA-Not Available

Table 20: Ammonia (ppm as Nitrogen) of Site Waters as Received at the BES Laboratory

		SITE LOCATION				
MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
	20-Oct-01	0.20	0.50	0.20	0.30	0.40
Oct-01	22-Oct-01	3.30	0 30	0.40	0.40	0.30
	24-Oct-01	3.80	0.40	0.40	0.30	0.20
	26-Nov-01	1.80	0.60	0.50	0.30	0.40
Nov-01	28-Nov-01	1.00	0.40	0.40	0.50	0.40
	30-Nov-01	0.90	0.40	0.40	0.40	0.60
	10-Dec-01	0.20	0.30	0.30	0.30	0.30
Dec-01	12-Dec-01	0.20	0.20	0.40	0.30	0.40
	14-Dec-01	0.20	0.40	0.60	0.40	0.30
	28-Jan-02	0.20	0.20	0.20	0.30	0.30
Jan-02	30-Jan-02	0.10	0.30	0.40	0.30	0.30
	1-Feb-02	0.20	0.30	0 20	0.20	4 00
	18-Feb-02	0.40	0.40	0.10	0.70	0 50
Feb-02	20-Feb-02	0.20	0.60	0.40	0.60	0.50
	22-Feb-02	0.30	0.70	0.70	0.60	0.50
	25-Mar-02	0.16	0.18	0.20	0.18	0.28
Mar-02	27-Mar-02	0.13	0.13	0.18	0.16	0.18
	29-Mar-02	0.13	0.20	0.23	NA	0.23
	22-Apr-02	0.18	0 23	0.16	0.36	0.20
Apr-02	24-Apr-02	0.40	0.38	0.23	0.38	0.10
	26-Apr-02	1.50	0.38	0.20	0.10	0.36
	20-May-02	0.23	0.23	0.33	0.60	0.20
May-02	22-May-02	0.20	0.30	0.18	0.28	0.13
	24-May-02	0.96	1.48	1.60	1.50	0.36
	24-Jun-02	0.48	0.43	0.36	1.43	0.38
Jun-02	26-Jun-02	0.43	0.43	0.56	0.73	0.36
	28-Jun-02	0.38	0.36	0.36	0.60	0.30
	22-Jul-02	0.30	0.56	0.26	0.86	0.23
Jul-02	24-Jul-02	0.23	0.56	0 26	0.63	0.28
	26-Jul-02	0.36	0.58	0.46	<0.10	0.38
	19-Aug-02	0.33	0.43	0.40	0.90	0.48
Aug-02	21-Aug-02	1.30	0.36	0.26	0.43	0.40
	23-Aug-02	0.46	0.58	0.40	0.58	0.48
	23-Sep-02	0.28	0.36	0.28	0.30	0.20
Sep-02	25-Sep-02	0.48	0.38	0.33	0.28	0.26
	27-Sep-02	0.53	0.28	0.38	0.28	0.33
	14-Oct-02	0.40	0.36	0.23	0.33	0.30
Oct-02	16-Oct-02	0.36	0.33	0.28	0.46	0.36
	18-Oct-02	0.36	0.38	0.33	0.48	0.38
	18-Nov-02	0.38	0.60	1 08	0.46	0.70
Nov-02	20-Nov-02	0.28	0.30	0.38	0.43	0.53
	22-Nov-02	0.38	0.60	0.53	0.53	0.53
	16-Dec-02	0.48	0.53	0.48	0.43	0.60
Dec-02	17-Dec-02	0.40	0.48	0.58	0.58	0.60
	20-Dec-02	0.43	0.33	0.46	0 33	0.36

NA-Not Available

Table 21: Total Chlorine (mg/L) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	Site B	Site C	Site D	Site F	Delta-Mendota Canal
		SITE LOCATION				
	20-Oct-01	0 60	0 10	0 20	0 20	0 10
Oct-01	22-Oct-01	0 30	0 30	0 20	0 40	<0 10
	24-Oct-01	0 10	0 10	0 20	0 30	0 10
	26-Nov-01	0 10	0 10	0 10	<0 10	<0 10
Nov-01	28-Nov-01	0 10	0 20	0 30	<0 10	0 10
	30-Nov-01	<0 10	<0 10	0 10	<0 10	<0 10
	10-Dec-01	0 20	0 20	0 10	0 20	0 10
Dec-01	12-Dec-01	0 20	0 20	0 20	0 20	<0 10
	14-Dec-01	0 20	0 10	0 20	0.20	0 10
	28-Jan-02	0 10	0 20	0 10	0 10	0 10
Jan-02	30-Jan-02	0 20	0 20	0 30	0 30	0 20
	1-Feb-02	0 20	0 20	0 10	0 20	0 20
	18-Feb-02	0 30	0 20	0 30	<0 10	0 30
Feb-02	20-Feb-02	0 20	0 20	0 20	<0 10	0 10
	22-Feb-02	0 10	0.20	0 10	0 10	0 30
	25-Mar-02	0 40	0 20	0.20	0 20	0 20
Mar-02	27-Mar-02	0 10	0 50	0 40	0 10	<0 10
	29-Mar-02	0 10	0 20	0 30	NA	0 20
	22-Apr-02	0 10	0 10	0 20	0 10	<0 10
Apr-02	24-Apr-02	0 20	0 10	0 10	0 10	0 10
	26-Apr-02	0.20	0 20	0 30	0 10	0 10
	20-May-02	0 73	0 23	0 26	0 23	0 10
May-02	22-May-02	0 28	0 16	0 33	0 10	<0 10
	24-May-02	0 16	0 16	<0 10	<0 10	<0 10
	24-Jun-02	<0 10	<0 10	<0 10	<0 10	<0 10
Jun-02	26-Jun-02	<0 10	0 58	<0 10	1 05	0 40
	28-Jun-02	0 13	0 10	0 18	0 15	0 13
	22-Jul-02	<0 10	0 13	<0 10	0 10	0 10
Jul-02	24-Jul-02	0 18	<0 10	0 10	<0 10	<0 10
	26-Jul-02	0 10	0 16	0 10	<0 10	<0 10
	19-Aug-02	2 50	0 20	0 50	0 20	<0 10
Aug-02	21-Aug-02	1 20	0 16	0 53	0 13	0 13
	23-Aug-02	0 26	0 10	0 18	0 18	<0 1
	23-Sep-02	0 90	0 33	0 40	0 26	0 20
Sep-02	25-Sep-02	0 26	0 43	0.30	<0 10	<0 10
	27-Sep-02	0 60	<0 10	0 38	0 20	0 10
	14-Oct-02	0.38	0 40	0 36	0 30	0 16
Oct-02	16-Oct-02	0 68	0 56	0 56	0 53	0 16
	18-Oct-02	0.56	0.36	0 53	0 28	0 16
	18-Nov-02	0 48	0 13	0 10	0 33	0 13
Nov-02	20-Nov-02	0 10	<0 10	<0 10	<0 10	<0 10
	22-Nov-02	0 13	<0 10	<0 10	0 18	<0 10
	16-Dec-02	<0 10	0 50	0 65	0 38	0 30
Dec-02	17-Dec-02	0 30	0 46	0 36	0 83	0 38
	20-Dec-02	0 10	<0 10	0 18	<0 10	<0 10

NA-Not Available

Site B

Figure 1. Site B Compared to Delta-Mendota Canal - *Daphnia magna* Short-term Acute Survival (data from Table 1)

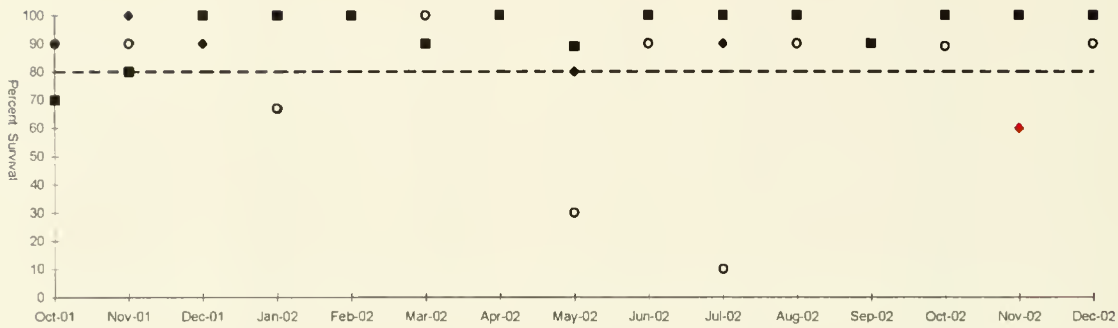


Figure 2. Site B Compared to Delta-Mendota Canal - *Pimephales promelas* 7-Day Acute Larval Survival (data from Table 2)

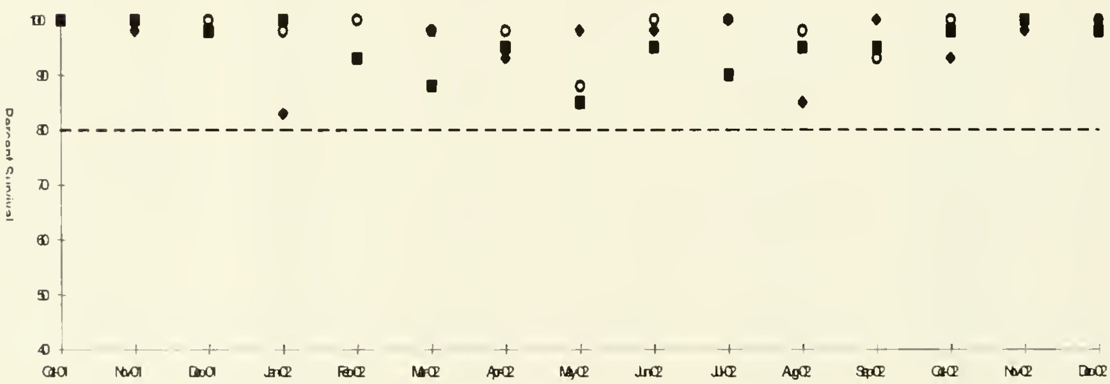


Figure 3. Site B Compared to Delta-Mendota Canal - *Daphnia magna* Short-Term Chronic Reproduction (Data from Table 3)

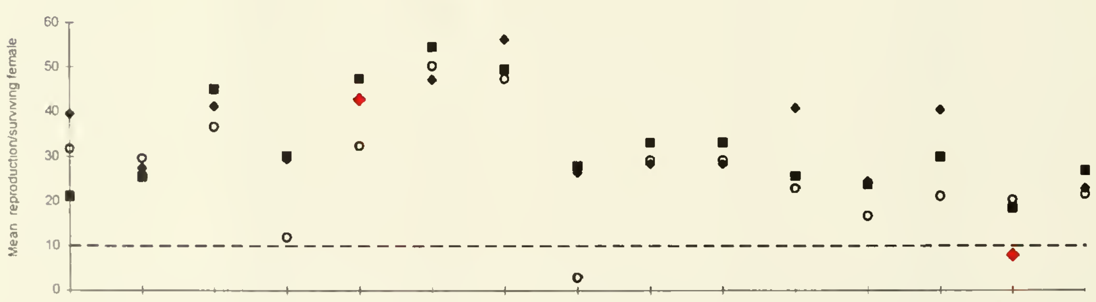


Figure 4. Site B Compared to Delta-Mendota Canal - *Pimephales promelas* 7-Day Chronic Larval Growth (data from Table 4)

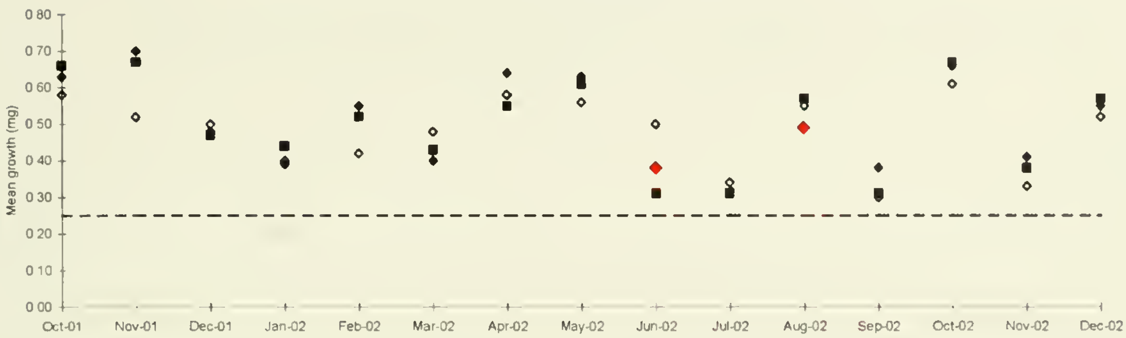
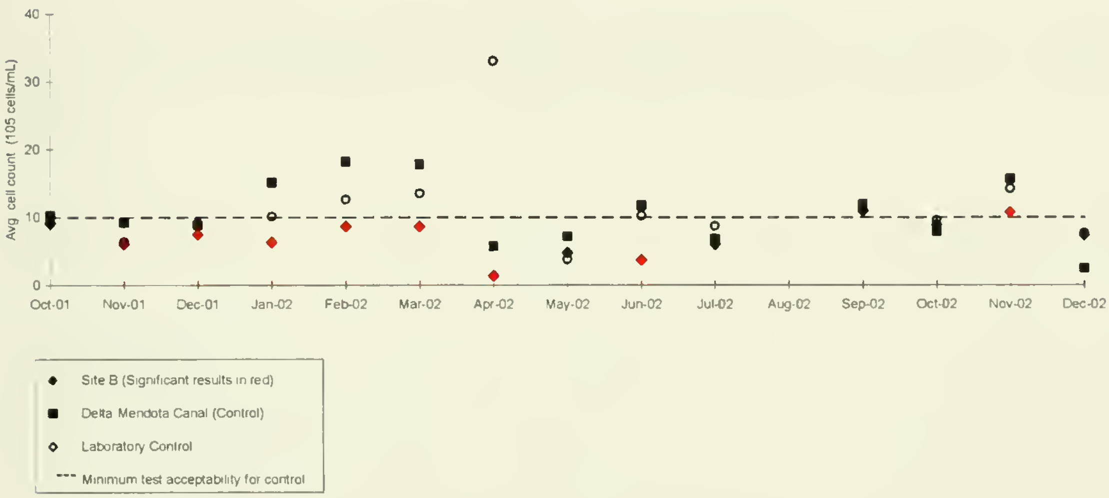


Figure 5. Site B Compared to Delta-Mendota Canal - *Selenastrum capricornutum* 96-hour Growth Tests (data from Table 5)



Site C

Figure 6. Site C Compared to Delta-Mendota Canal - *Daphnia magna* Short-term Acute Survival (data from Table 1)

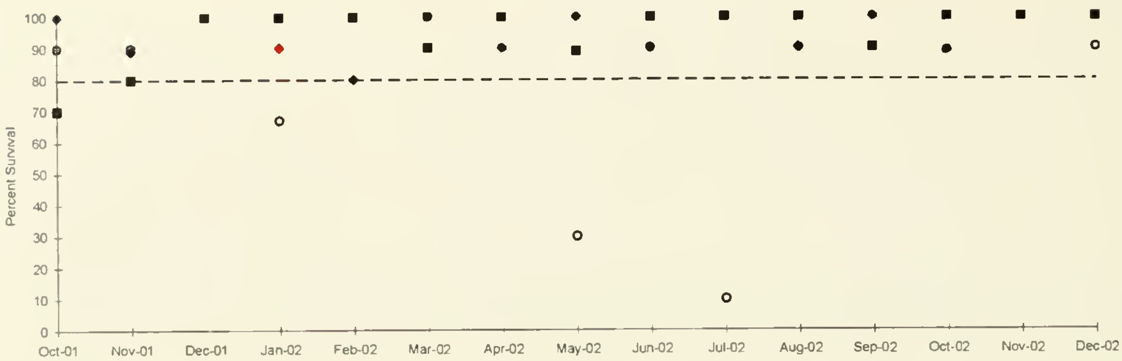


Figure 7. Site C Compared to Delta-Mendota Canal - *Pimephales promelas* 7-Day Acute Larval Survival (data from Table 2)

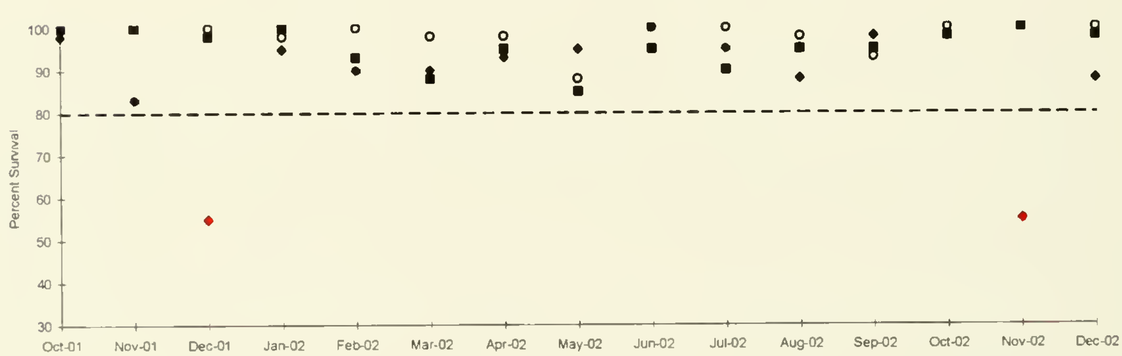


Figure 8. Site C Compared to Delta-Mendota Canal - *Daphnia magna* Short-term Chronic Reproduction (data from Table 3)

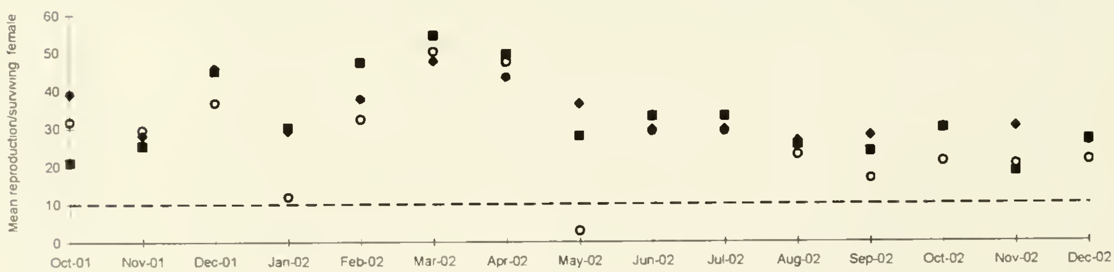


Figure 9. Site C Compared to Delta-Mendota Canal - Pimephales promelas 7-Day Chronic Larval Growth (data from Table 4)

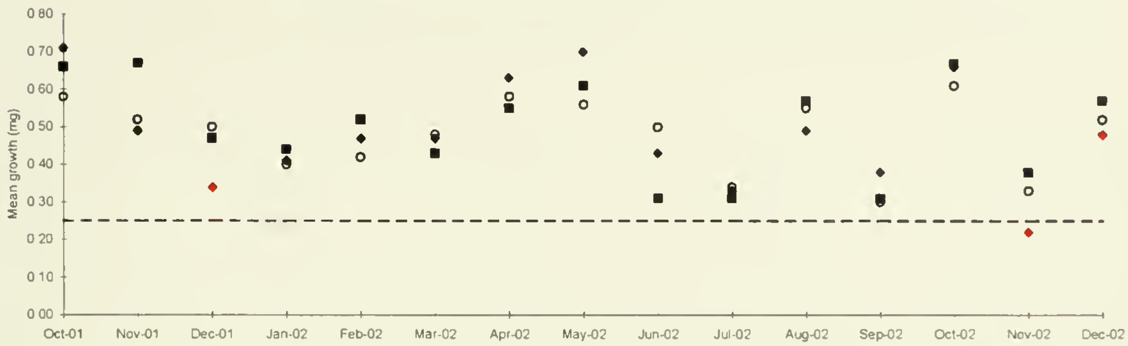
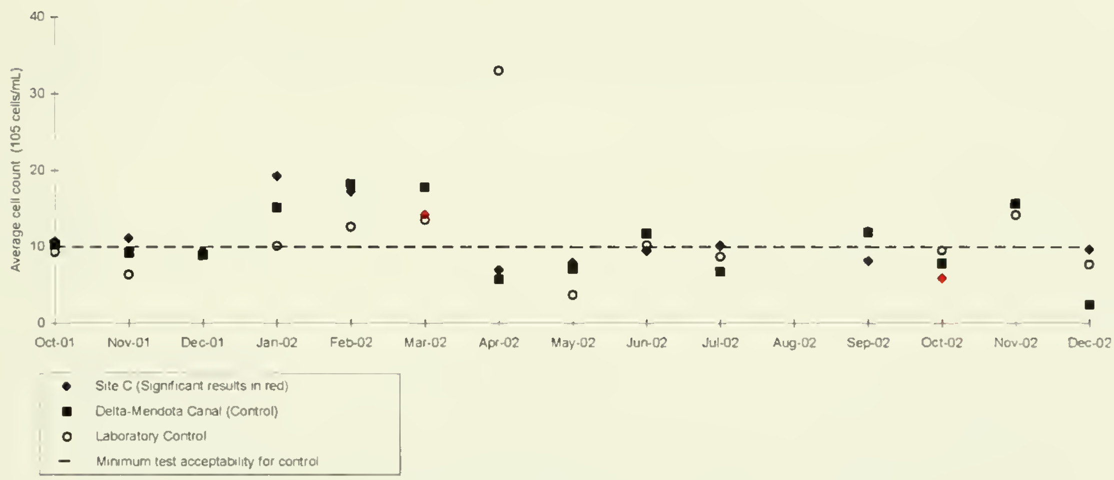


Figure 10. Site C Compared to Delta-Mendota Canal - Selenastrum capricornutum 96-hour Growth Tests (data from Table 5)



Site D

Figure 11. Site D Compared to Delta-Mendota Canal - *Daphnia magna* Short-term Acute Survival (data from Table 1)

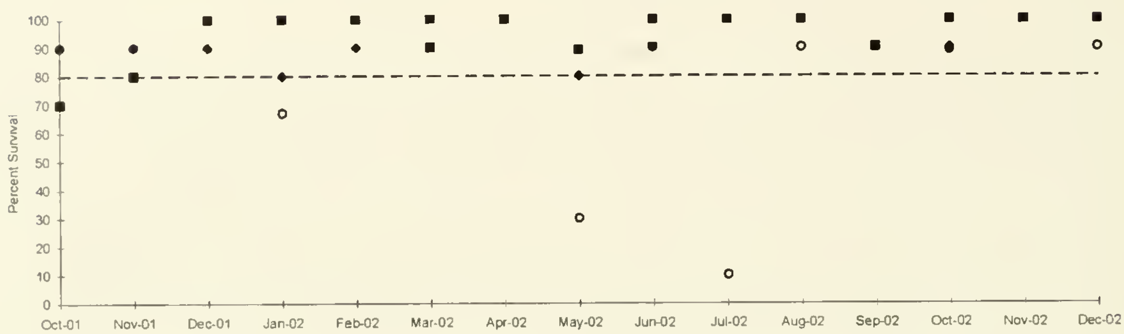


Figure 12. Site D Compared to Delta-Mendota Canal - *Pimephales promelas* 7-Day Acute Larval Survival (data from Table 2)

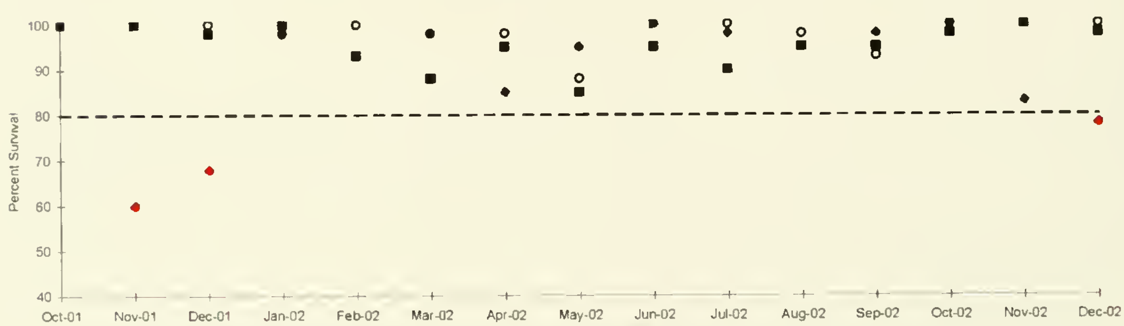


Figure 13. Site D Compared to Delta-Mendota Canal - *Daphnia magna* Short-term Chronic Reproduction (data from Table 3)

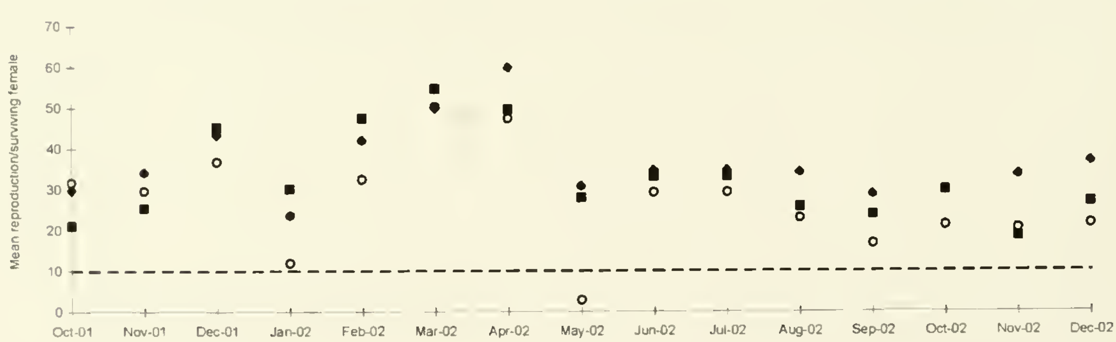


Figure 14. Site D Compared to Delta-Mendota Canal - *Pimephales promelas* 7-Day Chronic Larval Growth (data from Table 4)

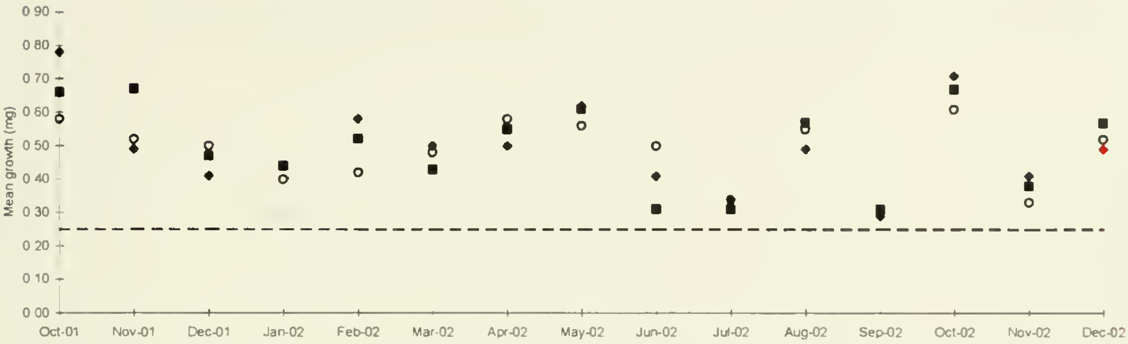
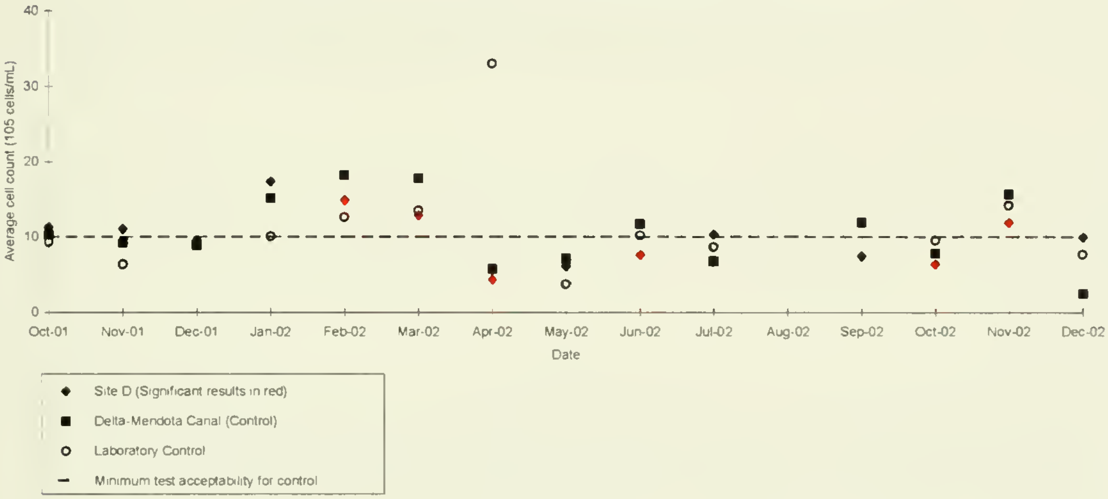


Figure 15. Site D Compared to Delta-Mendota Canal - *Selenastrum capricornutum* 96-hour Growth Tests (data from Table 5)



Site F

Figure 16. Site F Compared to Delta-Mendota Canal - Daphnia magna Short-term Acute Survival (data from Table 1)

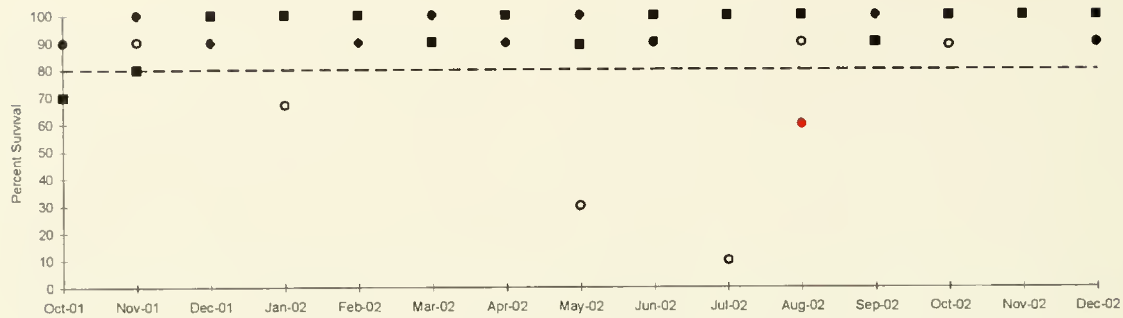


Figure 17. Site F Compared to Delta-Mendota Canal - Pimephales promelas 7-Day Acute Larval Survival (data from Table 2)

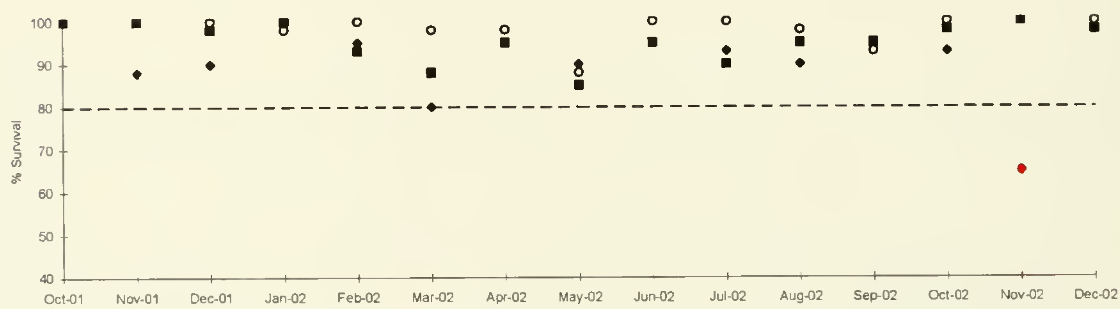


Figure 18. Site F Compared to Delta-Mendota Canal - Daphnia magna Short-term Chronic Reproduction (data from Table 3)

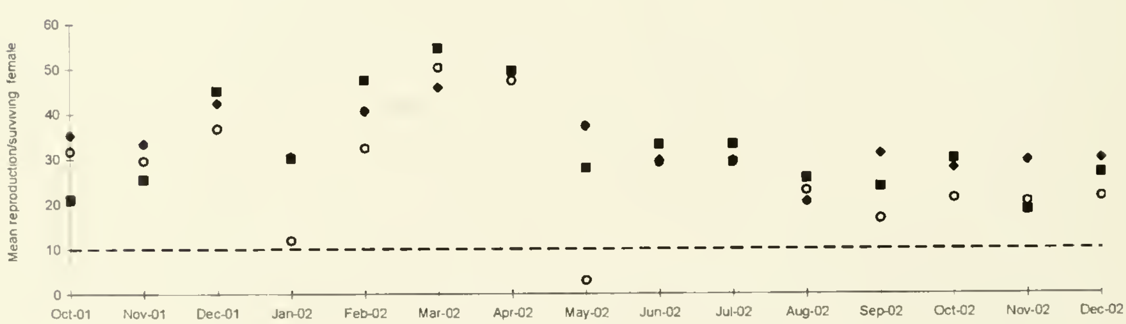


Figure 19. Site F Compared to Delta-Mendota Canal - Pimephales promelas 7-Day Chronic Larval Growth (data from Table 4)

Figure 20. Site F Compared to Delta-Mendota Canal - Selenastrum capricornutum 96-hour Growth Tests (data from Table 5)

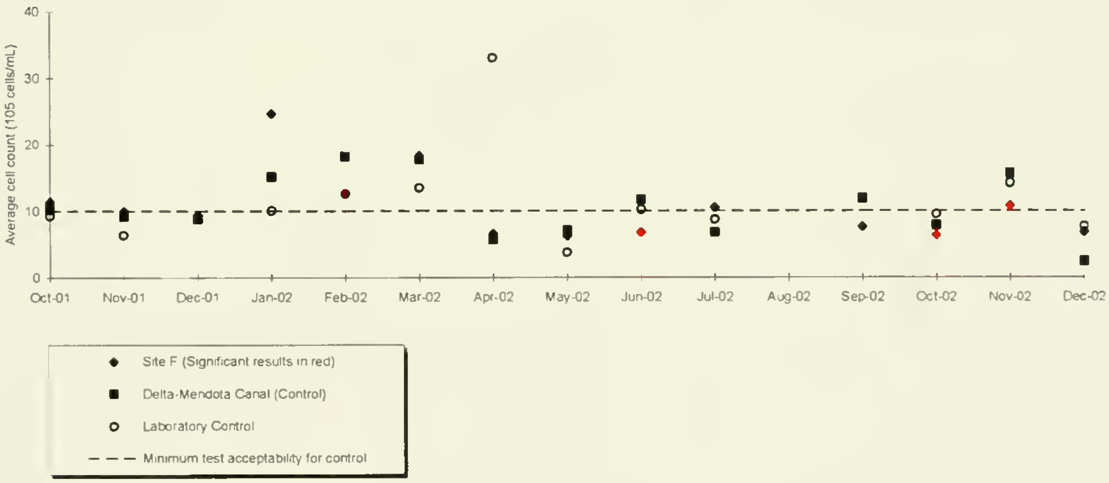


Figure 21a. Selenium Concentrations in San Luis Drain and Mud Slough

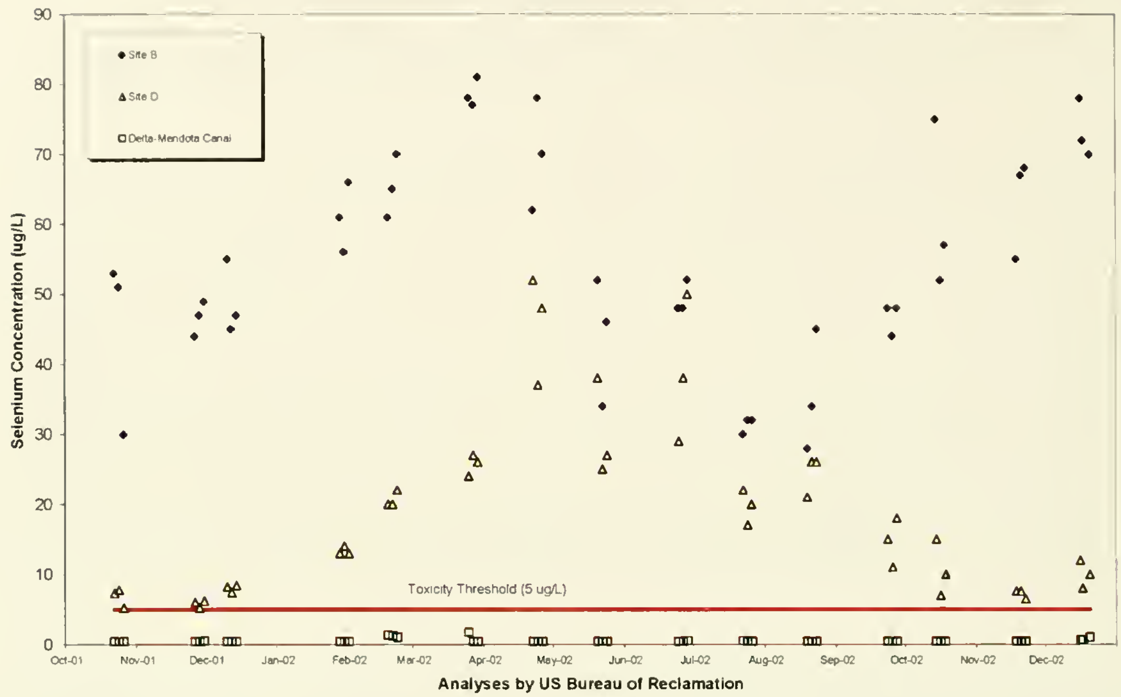
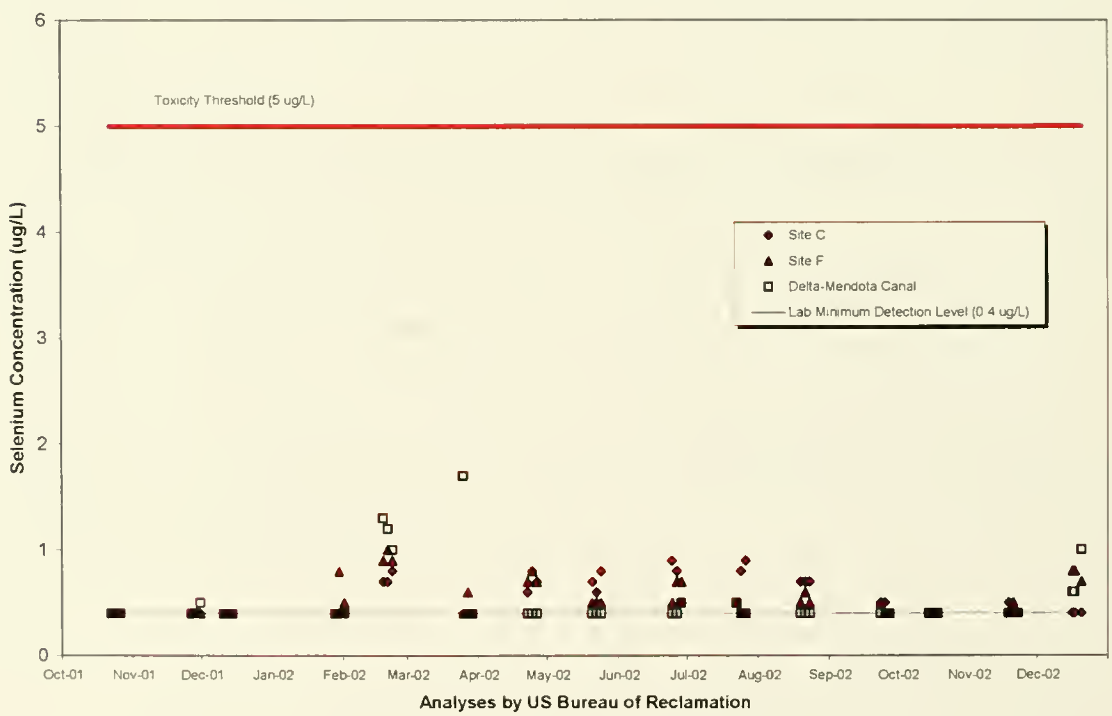


Figure 21b. Selenium Concentrations in Grassland Wetland Supply Channels



9

Sediment Monitoring

October 1, 2001 – December 31, 2002

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Grassland Bypass Project

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Purpose

Sediment monitoring for the Grassland Bypass Project (Project) focuses on measuring selenium and organic carbon parameters in the San Luis Drain (SLD), Mud Slough, and Salt Slough. The purpose of the monitoring is to assess the selenium concentrations in the sediment samples during the 9-year life of the Project's second phase. The measurements within the SLD provide selenium concentration estimates for comparison with California Department of Health Services' hazardous waste criterion. The measurements in Mud and Salt Sloughs provide selenium concentrations for comparison with US Fish and Wildlife Service thresholds for ecological risk.

Sampling Locations

Sampling locations for sediment monitoring in Mud Slough are located at Sites C, D, I2, and E and in Salt Slough at Site F. Sampling locations in the SLD are based on a probability sampling scheme associated with the amount of sediment estimated within each Check. Table 9 depicts how the 20 annual samples were chosen and the location. The estimated cubic yards for each check came from the annual survey made in November 2001 by the San Luis & Delta-Mendota Water Authority (Chapter 9, Annual Report, WY 2001, May 2003).

Sampling Frequency

Quarterly sampling periods were March, June, September and November for the 12-month period covered by the second year of Phase II. The program went a calendar year accounting system for Phase II. Sampling periods continue to correspond with the biota sampling events of the USFWS within the sloughs. Annual measurements are made in the SLD.

Sampling Methods

Sediment samples are collected using an acrylic coring device (4.5 cm diameter, 38 cm internal length). After collecting the sediment, sections of the core, 0-3 cm and 3-8 cm, are slowly extruded using a non-metallic internal pushing device and placed in distinct quart size mixing bowls. An additional sample is collected near the same spot for the whole-core sample and placed into a third mixing bowl. The process is continued until three samples along a transect are completed. Material from the 2nd and 3rd samples are placed in the corresponding 0-3 cm, 3-8 cm and whole-core mixing bowls containing the 1st samples. Each of the mixing bowls contain material from the transect. The 0-3 cm, 3-8 cm, and whole core samples are then mixed well in their mixing bowls in a manner similar to kneading bread. The mixing objective is to obtain one homogeneous sample in each of the bowls. Composited samples are then placed in a wide-mouth polyethylene container and stored in an ice chest at 4°C. Only whole-core samples are collected for the SLD.

Results

Tables 1 to 9 list the results of sediment analysis of samples collected between 1996 and 2002 from Mud Slough, Salt Slough, and the San Luis drain. All values are based on dry weight.

Figures 1 through 7 depict the selenium information with the help of bar charts. Figure 8 depicts the results of annual sediment whole core analysis at locations in the San Luis Drain. Further discussion is limited to selenium concentrations only. Data are compared to the following:

Guidelines (for Mud and Salt Slough):

- The recommended ecological risk guidelines for selenium concentrations in sediment (Table 1, Chapter 7) are as follows: "no effect" - less than 2 µg/g, dry weight, "level of concern" - 2 to 4 µg/g, dry weight, and "toxic" - greater than 4 µg/g, dry weight.

Criteria (for the San Luis Drain):

- The California Department of Health Services established a criterion for selenium concentration in sediment of 100 µg/g wet weight. Should the selenium concentrations in sediment from the SLD exceed this value, material dredged from the drain would have to be deposited in a hazardous waste site.

Ecological risk: Mud and Salt Slough

Selenium concentrations in the sediment from Mud Slough (Sites C, D, and E) and Salt Slough (Site F) were all below the 2.0 µg/g ("no effect level") for all 5 quarterly sampling periods representing the 1st year of Phase II. Selenium concentrations in the sediment from Mud Slough (Site I2) exceeded the 4.0 µg/g ("toxic effect level") for all periods.

Hazardous waste material criteria: San Luis Drain

Results from the annual survey are also depicted in table 1. The highest value from the 20 samples was 47 µg/g, dry weight. To make the comparison for hazardous waste criteria, the data needs to be converted to a wet weight basis. The formula used to make the comparison is as follows:

wet weight = (dry weight µg/g) * (1.0 - percent moisture/100.0).

The conversion for the value of 47 provides a wet weight concentrations of 20 µg/g, well below the standard.

Table 1. San Luis Drain (Station A) Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm ug/g, dry weight	3-8 cm ug/g, dry weight	Whole Core ug/g, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
Mar-13-1996	2	16	10	3.90	3.60	3.40	83.3	79.1	80.5
Jun-27-1996	8	20	29	4.33	5.01	2.96	83.8	78.3	71.2
Sep-04-1996	3	24	8	4.35	2.72	4.10	81.2	73.3	76.0
Nov-12-1996	22	62	55	2.92	3.10	3.72			
Mar-12-1997									
Jun-10-1997	3	4	5	0.89	1.55	2.10	55.0	58.0	62.0
Sep-11-1997	38	56	50	1.52	2.18	1.95	70.6	75.7	70.2
Nov-18-1997									
Mar-03-1998	18	150	98	1.21	2.89	2.28	52.9	63.3	65.0
Jun-04-1998	3	12	7	0.58	1.58	1.03	35.2	54.9	50.0
Sep-28-1998	9	23	52	1.06	1.17	2.25	55.0	55.3	67.9
Nov-10-1998	27	140	31	1.55	2.61	1.43	71.0	60.1	59.6
Feb-10-1999	3	15	11	1.32	1.45	1.10	69.3	65.0	59.1
Jun-17-1999	3	3	23	1.03	1.01	1.34	49.6	52.9	56.3
Sep-17-1999	43	16	30	1.11	1.23	2.05	61.4	59.5	68.4
Nov-18-1999	3	14	4	0.80	1.36	0.93	55.6	59.1	53.3
Mar-02-2000	3	2	2	0.71	0.83	0.98	47.3	48.3	51.4
Jun-06-2000	3	3	3	0.92	0.86	0.87	43.3	44.4	44.1
Sep-27-2000	32	62	70	2.99	2.32	1.81	73.1	70.7	67.9
Nov-14-2000	3	2	10	1.23	0.87	1.76	54.8	45.4	57.9
Mar-07-2001	4	4	4	1.13	1.45	1.21	43.5	45.3	48.1
Jun-06-2001	3	2	3	1.07	0.80	0.79	45.0	44.4	46.0
Maximum	43	150	98	4.35	5.01	4.10	83.8	79.1	80.5
Minimum	2	2	2	0.58	0.80	0.79	35.2	44.4	44.1
Median	3	16	11	1.17	1.50	1.79	55.0	59.1	59.6
Average	12	32	25	1.73	1.93	1.90	59.5	59.6	60.8

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March -September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - June 2001 samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit: Selenium, 0.01 ug/g
Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3
No sediment samples were collected at this site during the fifteen month study period (October 1, 2001 - December 31, 2001)

Table 2. San Luis Drain near terminus (Station B) Sediment Monitoring Results

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
Mar-12-1996									
Jun-27-1996	19	12	30	2.70	2.81	2.15	64.7	59.9	59.0
Sep-04-1996	11	18	20	3.85	3.75	2.08	66.5	61.7	51.2
Nov-12-1996	24	41	40	1.97	1.89	3.45			
Mar-13-1997	26	48	42	2.49	2.36	2.66			
Jun-10-1997	14	27	0	2.14	2.95	0.07	40.0	49.0	58.0
Sep-11-1997	21	61	48	2.39	2.82	1.84	65.9	61.4	53.8
Nov-18-1997	15	28	41	1.62	1.86	1.73	53.8	44.2	50.2
Mar-03-1998	18	41	45	1.46	1.70	1.73	50.8	51.4	54.3
Jun-03-1998	11	21	26	0.85	1.51	1.09	46.6	54.0	46.1
Sep-29-1998	13	15		1.51	1.64		85.9	79.5	NT
Nov-09-1998	17	17	17	1.68	1.74	1.76	73.2	80.8	56.7
Feb-09-1999	15	31	23	0.94	1.93	1.87	61.3	60.9	72.7
Jun-18-1999	17	27	31	1.45	1.84	1.28	56.1	61.4	47.1
Sep-16-1999	20	29	26	1.65	2.03	1.57	51.7	54.7	59.2
Nov-17-1999	38	21	39	2.23	1.96	1.92	58.8	55.6	55.9
Mar-01-2000	65	28	29	1.80	0.99	1.32	59.1	53.8	43.2
Jun-06-2000									
Sep-27-2000			19			0.62			40.9
Nov-14-2000									
Mar-07-2001	18	53	110	0.67	1.86	2.89	31.5	49.6	59.4
Maximum	65	61	110	3.85	3.75	3.45	85.9	80.8	72.7
Minimum	11	12	0	0.67	0.99	0.07	31.5	44.2	40.9
Median	18	28	30	1.68	1.89	1.76	58.8	55.6	54.3
Average	21	30	34	1.85	2.10	1.77	57.7	58.5	53.8

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March -September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - June 2001 samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit. Selenium, 0.01 ug/g
Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 3. Mud Slough above drainage discharge (Station C): Sediment Monitoring Results

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
Mar-12-1996									
May-20-1996	0.20	0.20	0.10	0.80	0.60	0.60	38.5	39.4	36.6
Jun-27-1996	0.10	0.05	0.10	0.49	0.40	0.14	34.0	30.0	25.2
Sep-04-1996	0.30	0.10	0.05	0.38	0.53	0.53	33.1	36.5	40.6
Nov-12-1996	0.16	0.17	0.31	0.26	0.28	0.95			
Mar-12-1997	0.15	0.05	0.11	0.35	0.28	0.68			
Jun-09-1997	0.11	0.20	0.05	0.31	0.27	0.16	30.0	53.0	28.0
Sep-11-1997	0.23	0.12	0.44	0.41	0.19	0.92	32.7	24.3	38.6
Nov-17-1997	0.10	0.10	0.10	0.27	0.18	0.32	28.7	26.7	65.5
Mar-03-1998									
Jun-04-1998	0.26	0.31	0.10	0.58	0.62	0.33	35.3	29.4	49.2
Sep-28-1998	0.40	0.35	0.31	0.77	0.70	0.53	40.7	39.1	35.2
Nov-09-1998	0.34	0.23	0.14	0.55	0.66	0.33	35.1	32.1	30.7
Feb-09-1999	0.20	0.13	0.51	0.28	0.21	0.85	33.5	30.7	34.2
Jun-18-1999	0.29	0.19	0.25	0.40	0.22	0.20	34.3	25.3	28.1
Sep-16-1999	0.27	0.32	0.25	0.60	0.67	0.54	36.9	35.5	36.8
Nov-17-1999	0.10	0.10	0.15	0.15	0.25	1.12	30.2	30.4	32.0
Mar-01-2000	3.90	0.05	0.05	2.08	0.37	0.45	28.4	34.8	31.6
Jun-07-2000	0.10	0.13	0.05	0.23	0.37	0.14	26.2	21.5	20.3
Sep-27-2000	0.16	0.17	0.15	0.42	0.41	0.32	30.0	30.1	28.0
Nov-14-2000	0.05	0.05	0.11	0.15	0.12	0.07	28.7	23.5	22.2
Mar-14-2001	0.19	0.23	0.40	0.33	0.28	0.59	25.5	24.8	29.3
Jun-04-2001	0.14	0.12	0.13	0.65	0.33	0.37	37.6	32.1	28.8
Aug-08-2001	0.16	0.19	0.16	0.46	0.43	0.41	30.0	26.5	32.1
Nov-13-2001	0.09	0.10	0.08	0.02	0.29	0.15	28.9	31.6	27.9
Mar-01-2002	0.10	0.23	0.10	0.07	0.34	0.10	27.6	28.4	24.4
Jun-18-2002	0.18	0.11	0.12	0.27	0.43	0.60	28.4	28.5	29.8
Sep-24-2002	0.19	0.13	0.15	0.39	0.29	0.39	22.4	25.5	29.1
Nov-13-2002	0.10	0.19	0.07	0.10	0.48	0.17	27.1	31.6	30.1
Maximum	3.90	0.35	0.51	2.08	0.70	1.12	40.7	53.0	65.5
Minimum	0.05	0.05	0.05	0.02	0.12	0.07	22.4	21.5	20.3
Median	0.16	0.13	0.12	0.38	0.34	0.39	30.0	30.1	30.1
Average	0.32	0.16	0.17	0.44	0.38	0.44	31.4	30.9	32.6

Notes:

All samples collected by the US Bureau of Reclamation, Sacramento CA

March -September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA

October 1996 - November 2002 samples analyzed by the US Geological Survey, Lakewood CO

Reporting Limit: Selenium, 0.01 ug/g

Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 4. Mud Slough below drainage discharge (Station D): Sediment Monitoring Results

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
Mar-12-1996									
Apr-03-1996	0.05	0.10	0.05	0.50	0.50	0.50	23.9	25.2	23.7
Jun-27-1996	0.40	0.40	0.20	0.26	0.35	0.19	32.9	26.2	28.5
Sep-04-1996	0.20	0.20	0.20	0.22	0.20	0.20	25.8	27.0	26.5
Nov-13-1996	0.14	0.25	0.17	0.14	0.12	0.12			
Mar-12-1997	0.46	0.27	0.76	0.28	0.17	0.28			
Jun-09-1997	0.12	0.05	0.16	0.07	0.06	0.11	21.0	21.0	25.0
Sep-11-1997	0.53	0.29	0.33	0.24	0.22	0.16	27.7	28.5	22.6
Nov-17-1997	0.72	0.24	0.24	0.54	0.09	0.14	30.4	25.8	18.8
Mar-03-1998									
Jun-03-1998	0.63	1.20	1.30	0.26	1.10	0.68	27.2	34.8	38.9
Sep-29-1998	0.64	0.47	0.50	0.29	0.27	0.21	34.6	27.7	26.5
Nov-10-1998	0.34	0.23	0.45	0.15	0.13	0.18	30.0	29.2	33.3
Feb-09-1999	0.29	0.40	0.38	0.18	0.27	0.51	26.6	28.0	32.6
Jun-18-1999	0.60	0.60	0.83	0.79	0.54	0.72	38.0	35.6	35.6
Sep-16-1999	0.68	0.53	0.81	0.44	0.51	0.85	36.7	35.0	39.8
Nov-17-1999	0.81	0.54	0.67	0.60	0.55	0.42	40.4	33.7	29.5
Mar-01-2000	0.71	0.83	0.34	0.41	1.10	0.19	33.6	31.2	19.8
Jun-07-2000	0.12	0.14	0.17	0.16	0.15	0.19	23.0	20.8	21.9
Sep-27-2000	0.39	0.22	0.35	0.18	0.13	0.22	37.0	25.8	23.5
Nov-14-2000	0.11	0.12	0.24	0.13	0.13	0.08	29.0	24.1	16.2
Mar-14-2001	0.21	0.23	0.23	0.06	0.09	0.06	18.2	19.8	20.2
Jun-04-2001	0.20	0.19	0.20	0.17	0.14	0.13	24.1	26.0	25.0
Aug-08-2001	0.26	0.19	0.14	0.14	0.12	0.09	24.5	18.0	20.5
Nov-13-2001	0.15	0.18	0.09	0.15	0.06	0.08	24.1	25.1	25.5
Mar-01-2002	0.11	0.10	0.16	0.08	0.08	0.01	19.6	18.8	23.3
Jun-18-2002	0.14	0.10	0.14	0.14	0.12	0.12	25.8	22.5	24.5
Sep-24-2002	0.50	0.32	0.22	0.12	0.14	0.09	25.4	22.5	18.4
Nov-13-2002	0.34	0.20	0.28	0.07	0.05	0.08	19.7	22.0	22.5
Maximum	0.81	1.20	1.30	0.79	1.10	0.85	40.4	35.6	39.8
Minimum	0.05	0.05	0.05	0.06	0.05	0.01	18.2	18.0	16.2
Median	0.34	0.23	0.24	0.18	0.14	0.18	26.6	25.8	24.5
Average	0.36	0.32	0.36	0.25	0.27	0.24	28.0	26.2	25.7

Notes
All samples collected by the US Bureau of Reclamation, Sacramento CA
March -September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - November 2002 samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit Selenium, 0 01 ug/g
Significant Digits. Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 5. Mud Slough at Highway 140 (Station E): Sediment Monitoring Results

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
Mar-12-1996									
May-20-1996	0.10	0.10	0.10	0.70	1.00	0.70	41.1	35.8	34.5
Jun-27-1996	0.10	0.10	0.50	1.08	0.45	0.40	37.9	32.7	30.9
Sep-04-1996									
Nov-13-1996	0.72	0.71	0.70	0.38	0.30	0.31			
Mar-13-1997	0.82	1.00	1.00	0.12	0.16	0.06			
Jun-09-1997	1.50	1.60	1.50	0.65	0.72	0.74	44.0	40.0	44.0
Sep-11-1997	1.60	1.30	1.90	0.69	0.52	0.78	42.0	34.2	45.8
Nov-17-1997	0.83	2.00	1.20	0.29	0.31	0.39	29.3	27.7	29.3
Mar-03-1998									
Jun-03-1998									
Sep-29-1998	0.24	0.18	0.25	0.16	0.18	0.21	31.6	26.7	26.8
Nov-10-1998	0.25	0.18	0.30	0.13	0.15	0.39	31.8	25.6	32.5
Feb-09-1999	0.32	0.48	0.78	0.32	0.54	0.45	37.4	38.0	43.5
Jun-18-1999	0.48	0.30	0.47	0.24	0.16	0.32	33.1	27.4	49.7
Sep-17-1999	0.96	0.54	0.20	0.44	0.24	0.08	44.0	29.9	8.2
Nov-18-1999	0.38	0.17	0.39	0.17	0.13	0.26	28.0	28.4	30.7
Mar-02-2000	0.19	0.13	0.23	0.32	0.13	0.23	36.0	36.2	27.1
Jun-07-2000	0.29	0.26	0.78	0.19	0.19	0.30	26.6	19.1	30.4
Sep-27-2000	0.54	0.46	0.93	0.20	0.23	0.51	33.4	29.3	29.4
Nov-14-2000	0.56	0.18	0.32	0.30	0.14	0.22	20.0	17.5	20.2
Mar-14-2001	0.68	0.54	0.36	0.40	0.07	0.11	29.6	26.2	27.0
Jun-06-2001	0.33	0.78	0.55	0.18	0.28	0.27	28.0	30.2	19.7
Aug-08-2001	0.36	0.47	0.59	0.14	0.24	0.24	20.2	21.7	25.1
Nov-13-2001	0.80	0.45	0.31	0.25	0.37	0.15	26.7	32.3	28.0
Mar-01-2002	0.38	0.46	0.74	0.15	0.20	0.26	24.6	20.6	26.8
Jun-19-2002	0.77	1.10	0.48	0.37	0.46	0.31	34.7	32.7	28.3
Sep-24-2002	0.51	0.41	0.81	0.16	0.21	0.45	23.9	22.7	32.0
Nov-13-2002	1.50	1.20	1.10	0.58	0.54	0.57	42.7	37.9	39.7
Maximum	1.60	2.00	1.90	1.08	1.00	0.78	44.0	40.0	49.7
Minimum	0.10	0.10	0.10	0.12	0.07	0.06	20.0	17.5	8.2
Median	0.51	0.46	0.55	0.29	0.24	0.31	31.8	29.3	29.4
Average	0.61	0.60	0.66	0.34	0.32	0.35	32.5	29.3	30.9

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
March -September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - November 2002 samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit: Selenium, 0.01 ug/g
Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 6. Salt Slough at Highway 165 (Station F): Sediment Monitoring Results

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
Mar-12-1996									
Jun-27-1996	0.60	0.50	0.20	0.69	0.58	0.18	41.9	33.3	28.9
Sep-05-1996	0.40	0.80	0.40	0.44	0.75	0.25	38.7	40.6	29.7
Nov-13-1996	0.24	0.40	0.25	0.05	0.16	0.05			
Mar-13-1997	0.94	0.36	0.57	0.56	0.36	0.32			
Jun-09-1997	0.12	0.14	0.35	0.08	0.12	0.26	26.0	20.0	29.0
Sep-12-1997	0.59	0.73	0.74	0.23	0.22	0.23	28.0	26.9	23.8
Nov-18-1997	1.30	1.90	1.40	1.16	1.43	1.12	47.3	46.9	44.6
Mar-04-1998	2.10	1.80	1.60	2.32	1.97	2.11	42.0	70.0	42.2
Jun-04-1998	0.66	1.00	1.30	0.49	0.59	1.48	34.8	31.2	50.7
Sep-29-1998	0.33	0.48	0.59	0.26	0.31	0.23	26.8	26.1	29.2
Nov-10-1998	0.28	0.55	0.70	0.21	0.26	0.33	26.7	33.7	29.0
Feb-09-1999	0.59	0.56	0.93	0.40	0.32	0.19	33.1	30.5	31.6
Jun-18-1999	0.37	0.52	0.70	0.22	0.27	0.37	29.8	26.3	28.5
Sep-17-1999	0.53	0.65	0.62	0.49	0.53	0.22	35.5	36.8	28.6
Nov-18-1999	0.27	0.25	0.42	0.33	0.24	0.26	36.5	28.9	29.3
Mar-02-2000	0.35	0.45	0.59	0.29	0.26	0.32	23.8	23.3	21.2
Jun-07-2000	0.30	0.37	0.52	0.24	0.24	0.35	27.9	24.6	20.5
Sep-27-2000	0.43	0.68	0.53	0.34	0.24	0.34	36.8	37.1	33.8
Nov-14-2000	0.22	0.39	0.52	0.18	0.25	0.20	25.6	25.2	27.0
Mar-14-2001	0.38	0.22	0.77	0.40	0.23	0.48	29.1	26.7	37.0
Jun-06-2001	0.66	0.44	0.73	0.21	0.22	0.27	27.4	24.5	25.3
Aug-08-2001	0.36	0.70	0.56	0.31	0.18	0.34	28.4	21.4	21.5
Nov-13-2001	0.20	0.23	0.30	0.38	0.42	0.46	28.9	31.0	27.6
Mar-01-2002	0.43	0.73	0.46	0.69	0.20	0.55	36.4	20.5	25.6
Jun-19-2002	0.36	0.71	0.24	0.27	0.31	0.29	25.5	28.2	26.4
Sep-24-2002	0.29	0.37	0.57	0.36	0.23	0.28	29.6	21.2	20.1
Nov-13-2002	0.51	0.59	0.28	0.30	0.20	0.16	28.1	28.0	28.3
Maximum	2.10	1.90	1.60	2.32	1.97	2.11	47.3	70.0	50.7
Minimum	0.12	0.14	0.20	0.05	0.12	0.05	23.8	20.0	20.1
Median	0.38	0.52	0.57	0.33	0.26	0.29	29.1	28.0	28.6
Average	0.51	0.61	0.62	0.44	0.41	0.43	31.8	30.5	29.6

Notes
All samples collected by the US Bureau of Reclamation, Sacramento CA
March -September 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
October 1996 - November 2002 samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit. Selenium, 0.01 ug/g
Significant Digits Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 7. Mud Slough backwater (Station I and I - 2): Sediment Monitoring Results

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
Jun-13-1996	0.40	0.40	0.30	1.60	1.30	1.20	7.8	17.2	24.9
Mar-13-1997	1.50	0.80	0.40	1.76	0.79	0.56			
Jun-03-1998	0.30	0.20	0.20	0.47	0.69	0.55	26.4	20.6	20.3
Jun-18-1999	4.80	4.50	4.40	1.90	1.89	1.96	16.1	25.1	25.9
Mar-01-2000	0.16	1.70	0.99	0.43	1.35	0.90	44.3	33.7	30.8
Jun-07-2001	4.40	2.20	1.70	1.92	1.55	1.39	4.6	20.9	20.1
Nov-14-2000	3.50	1.50	2.20	1.91	1.17	1.23	39.6	29.1	33.8
Mar-14-2001	0.81	1.30	1.60	0.80	1.16	1.01	28.3	30.5	33.3
Jun-06-2001	0.48	0.25	0.35	0.49	0.57	0.52	36.5	34.3	32.2
Aug-08-2001	0.34	0.32	0.21	0.26	0.28	0.14	22.9	24.1	25.0
Nov-14-2001	6.10	3.70	3.50	1.93	1.51	1.63	60.9	48.2	49.8
Mar-01-2002	8.30	5.70	2.60	2.65	2.58	2.04	59.6	58.1	51.1
Jun-18-2002	8.50	4.70	6.20	2.17	2.10	1.89	61.4	53.3	57.3
Sep-24-2002	7.00	4.50	3.80	1.70	0.62	1.84	56.3	49.6	52.8
Nov-13-2002	5.00	3.00	2.70	2.10	2.38	1.70	57.7	56.9	48.5
Maximum	8.50	5.70	6.20	2.65	2.58	2.04	61.4	58.1	57.3
Minimum	0.16	0.20	0.20	0.26	0.28	0.14	4.6	17.2	20.1
Median	3.50	1.70	1.70	1.76	1.30	1.23	38.1	32.1	32.8
Average	3.44	2.32	2.08	1.47	1.33	1.24	37.3	35.8	36.1

Notes:
All samples collected by the US Bureau of Reclamation, Sacramento CA
June 1996 samples analyzed by US Bureau of Reclamation, Sacramento CA
March 1997 - November 2002 samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit: Selenium, 0.01 ug/g
Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 8. San Luis Drain Annual Sediment Monitoring Results June 1997 – June 2001

Sampling Date	Selenium Concentration 0-3 cm ug/g, dry weight	Selenium Concentration 3-8 cm ug/g, dry weight	Selenium Concentration Whole Core ug/g, dry weight	Organic Carbon 0-3 cm %	Organic Carbon 3-8 cm %	Organic Carbon Whole Core %	Percent Moisture 0-3 cm %	Percent Moisture 3-8 cm %	Percent Moisture Whole Core %
30' South of Check 1 (1-2 C)									
Jun-10-1997	9.6	47.0	26.0	1.19	1.93	1.69	36.0	51.0	52.0
Jun-03-1998	22.0	9.7	29.0	1.49	1.49	1.55	49.7	44.8	44.9
Jun-16-1999	5.3	8.5	59.0	0.81	0.97	2.13	50.2	39.8	58.7
Jun-05-2000	14.0	15.0	15.0	1.33	1.55	1.11	54.0	53.6	40.1
Jun-05-2001	8.9	11.0	14.0	1.53	1.59	1.78	61.3	54.7	60.3
Midpoint of Checks 1 & 2 (1-2 B)									
Jun-10-1997	39.0	96.0	51.0	2.11	2.25	1.56	56.0	53.0	47.0
Jun-03-1998	64.0	68.0	8.3	1.53	1.71	1.31	56.3	52.7	55.4
Jun-16-1999	8.8	11.0	14.0	1.30	1.45	1.53	62.9	57.6	55.8
Jun-05-2000	9.4	8.4	18.0	1.35	1.27	1.46	65.9	59.6	57.1
Jun-05-2001	9.5	8.0	12.0	1.66	1.32	1.60	66.5	57.8	60.0
50' North of Check 2 (1-2 A)									
Jun-10-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-03-1998	15.0	NT	21.0	0.65	NT	0.97	42.6	NT	38.2
Jun-16-1999	19.0	64.0	71.0	1.99	2.68	2.27	35.5	49.0	54.9
Jun-05-2000	14.0	29.0	67.0	0.85	1.12	1.66	25.0	32.2	44.1
Jun-05-2001	18.0	71.0	48.0	1.05	1.90	1.92	19.7	43.6	43.2
50' South of Check 10 (10-11 C)									
Jun-10-1997	7.2	15.0	31.0	1.28	1.34	2.67	50.0	57.0	42.0
Jun-04-1998	21.0	39.0	17.0	0.72	1.66	1.43	44.0	62.6	56.4
Jun-16-1999	19.0	75.0	16.0	0.93	2.07	1.34	43.8	61.5	52.8
Jun-05-2000	47.0	84.0	41.0	1.23	1.65	1.85	49.6	57.1	60.9
Jun-05-2001	39.0	140.0	33.0	1.32	3.05	1.74	36.0	65.5	52.0
Midpoint of Checks 10 & 11 (10-11 B)									
Jun-10-1997	11.0	12.0	NT	1.57	1.16	NT	59.0	48.0	NT
Jun-04-1998	7.5	8.7	17.0	0.91	0.93	1.43	54.0	45.1	72.6
Jun-16-1999	26.0	8.4	6.0	1.24	0.89	0.56	51.5	52.8	39.4
Jun-05-2000	7.5	22.0	5.8	1.28	0.99	0.93	61.4	52.8	53.2
Jun-05-2001	10.0	14.0	10.0	1.40	1.86	1.43	54.1	60.7	61.8

Table 8 (Cont). San Luis Drain Annual Sediment Monitoring Results June 1997 - June 2001

	Selenium Concentration			Organic Carbon			Percent Moisture		
Sampling Date	0-3 cm ug/g, dry weight	3-8 cm ug/g, dry weight	Whole Core ug/g, dry weight	0-3 cm %	3-8 cm %	Whole Core %	0-3 cm %	3-8 cm %	Whole Core %
50' North of Check 11 (10-11 A)									
Jun-10-1997	24.0	43.0	39.0	1.41	1.97	1.83	48.0	57.0	53.0
Jun-04-1998	18.0	55.0	50.0	1.14	2.57	1.68	47.2	61.2	53.5
Jun-16-1999	14.0	26.0	45.0	0.61	1.82	1.56	34.7	47.1	53.1
Jun-05-2000	12.0	58.0	51.0	0.66	2.55	1.69	32.1	64.4	54.1
Jun-05-2001	16.0	64.0	50.0	1.25	2.51	2.31	36.3	59.8	50.4
50' South of Check 14 (14-15 C)									
Jun-11-1997	7.1	34.0	8.0	1.54	2.62	1.93	63.0	70.0	63.0
Jun-04-1998	31.0	11.0	42.0	0.85	1.96	1.11	45.2	67.4	42.3
Jun-16-1999	4.0	11.0	13.0	1.00	1.87	1.30	60.3	63.6	62.0
Jun-05-2000	5.3	4.8	45.0	1.34	1.36	2.41	60.6	41.0	63.1
Jun-05-2001	4.9	4.8	14.0	1.11	1.17	2.66	52.1	51.3	62.5
Midpoint of Checks 14 & 15 (14-15 B)									
Jun-11-1997	2.9	22.0	10.0	0.38	1.11	1.91	29.0	49.0	56.0
Jun-04-1998	3.4	3.4	5.7	1.04	1.08	1.17	55.2	54.9	58.0
Jun-17-1999	3.0	3.1	3.0	0.95	0.96	0.94	58.0	56.0	52.6
Jun-06-2000	3.3	4.1	3.1	1.03	0.99	0.93	56.0	52.5	53.3
Jun-05-2001	5.1	4.7	5.1	1.24	1.15	1.19	61.5	56.8	57.6
50' North of Check 15 (14-15 A)									
Jun-11-1997	40.0	48.0	3.8	2.37	2.83	0.59	63.0	67.0	63.0
Jun-04-1998	29.0	47.0	59.0	1.46	2.87	3.21	51.8	65.5	68.7
Jun-17-1999	43.0	76.0	76.0	3.64	3.23	2.84	61.9	65.2	63.5
Jun-06-2000	23.0	76.0	55.0	0.79	2.42	2.32	35.3	53.5	53.0
Jun-05-2001	43.0	76.0	62.0	2.13	2.93	2.37	37.4	62.2	56.9
Midpoint of Checks 17 & 18 (17-18 B)									
Jun-10-1997	2.7	3.5	3.8	0.67	0.80	1.82	46.0	45.0	66.0
Jun-03-1998	2.0	2.8	2.7	0.57	0.83	0.90	24.8	34.1	44.9
Jun-17-1999	2.3	1.6	1.6	0.59	0.71	0.52	45.5	37.9	40.3
Jun-06-2000	2.2	2.0	1.9	0.76	0.66	0.59	36.3	38.9	38.9
Jun-06-2001	1.8	2.0	2.1	0.47	0.60	0.54	34.3	35.6	39.6
50' North of Check 18 (17-18 A)									
Jun-10-1997	48.0	66.0	100.0	2.37	1.92	2.98	57.0	54.0	60.0
Jun-03-1998	35.0	65.0	75.0	1.25	2.39	2.33	38.0	53.8	57.4
Jun-17-1999	38.0	100.0	87.0	1.11	5.19	3.16	47.6	62.2	61.6
Jun-06-2000	26.0	49.0	43.0	0.81	1.84	1.54	35.6	47.9	45.7
Jun-06-2001	11.0	32.0	50.0	0.96	2.10	1.96	40.7	58.8	46.7

Notes: All samples collected by the US Bureau of Reclamation, Sacramento CA
All samples analyzed by the US Geological Survey, Lakewood CO
Reporting Limit: Selenium, 0.01 ug/g
Significant Digits: Selenium, 2 Organic Carbon, 2 or 3 Percent Moisture, 2 or 3

Table 9. Annual sediment sampling in the San Luis Drain, June 2002

San Luis Drain Check Number	Miles Between Checks	Volume survey results November 2001: Estimated Cubic Yards (1)	Volume survey results November 2001: Accumulated Cubic yards	Sample Selection (2): Sample Allocation 20 samples (3)	Sample Selection (2): n = 20 Sample Numbers (3)	Sample Selection (2): Selected "cubic yard" (3)	Sampling Date (4)	Sediment Analysis June 2002: Selenium Concentration (5) Whole Core ug/g, dry weight	Sediment Analysis June 2002: Total Organic Carbon (5) Whole Core %	Sediment Analysis June 2002: Percent Moisture (5) Whole Core %
0 (6)	2.64	5,611	5,611	1	1	3,000	2002-06-18	16	1.51	61.1
1	1.82	5,487	11,098	2	2	9,791	2002-06-24	16	1.17	51.9
2	0.28	1,748	12,846							
3	2.57	6,404	19,250	3	3	16,582	2002-06-24	17	1.45	63.4
4	1.80	9,836	29,086	4	4	23,372	2002-06-24	24	2.19	67.9
5	2.06	6,481	35,567	5	5	30,163	2002-06-24	12	1.45	70.6
6	0.83	2,321	37,888	6	6	36,953	2002-06-24	14	1.93	74.2
7	0.45	2,842	40,730							
8	0.47	1,600	42,330							
9	3.20	9,364	51,694	7,8	7	43,744	2002-06-24	25	1.17	51.4
					8	50,534	2002-06-24	7.8	1.13	57.7
10	1.46	3,835	55,529							
11	2.50	10,900	66,429	9,10	9	57,325	2002-06-24	47	1.79	57.9
					10	64,115	2002-06-24	12	1.24	67.5
12	0.46	1,966	68,395							
13	0.91	4,378	72,773	11	11	70,906	2002-06-24	4.5	0.96	65.6
14	1.34	14,917	87,690	12,13	12	77,696	2002-06-24	6.0	1.47	67.4
					13	84,487	2002-06-24	3.9	0.92	63.1
15	0.96	18,661	106,351	14,15,16	14	91,277	2002-06-24	4.6	1.23	63.3
					15	98,068	2002-06-24	4.5	1.03	60.7
					16	104,858	2002-06-24	4.7	1.45	60.7
16	1.68	21,132	127,483	17,18,19	17	111,649	2002-06-25	4.0	1.08	56.9
					18	118,439	2002-06-25	3.9	1.00	54.6
					19	125,230	2002-06-25	3.7	0.98	54.1
17	0.68	4,900	132,383	20	20	132,020	2002-06-25	2.7	0.71	44.3
18 (7)	0.97	3,427	135,810							
Total	27.08	135,810								

Notes: (1) Sediment volume and distribution measured by San Luis and Delta-Mendota Water Authority, November 2001
(2) Sampling program designed by Bob Young, US Bureau of Reclamation
(3) Sampling interval using 20 samples = 6,791feet
(4) All samples collected by the US Bureau of Reclamation, Sacramento CA, June 2002
(5) All samples analyzed by the US Geological Survey, Lakewood CO, September 2002
(6) Close to San Luis Drain near terminus (Station B)
(7) Close to San Luis Drain near South Dos Palos (Station A)

Figure 1. Selenium in Sediment at Station A (1996 - 2002)

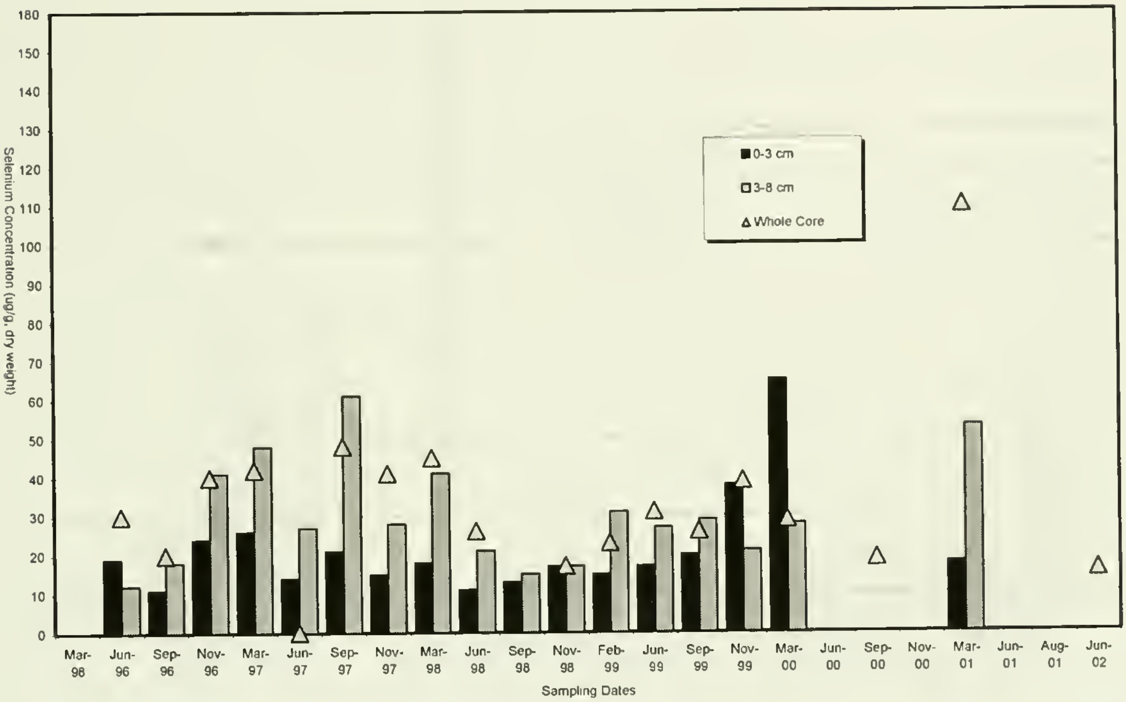


Figure 2. Selenium in Sediment at Station B (1996 - 2002)

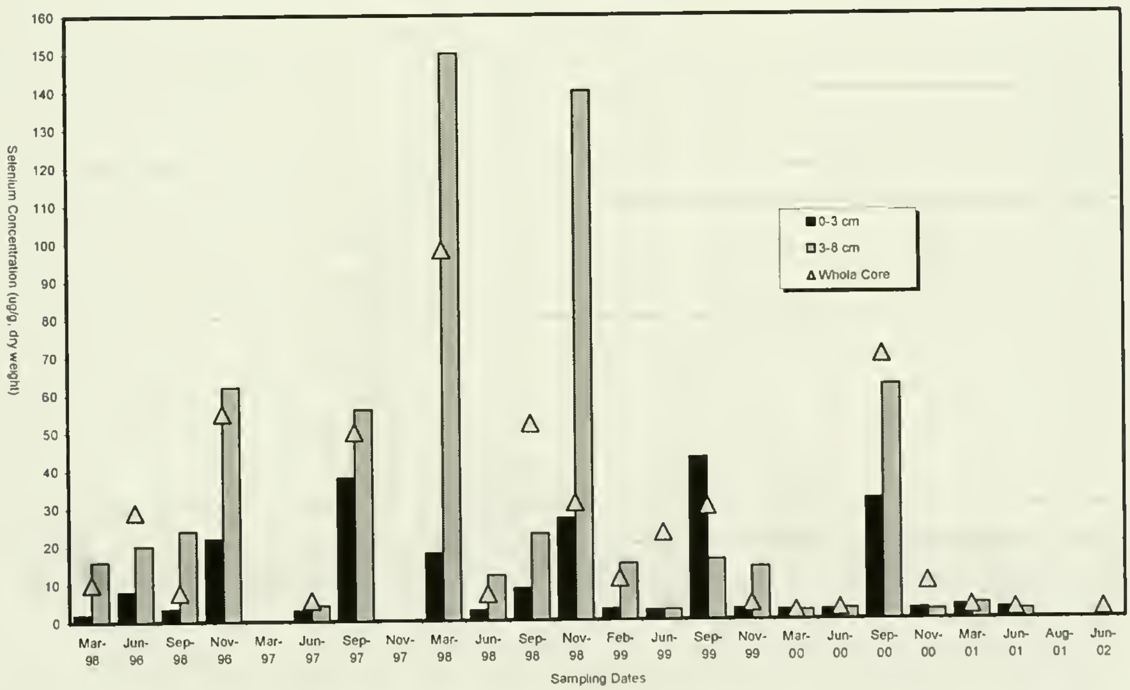


Figure 3. Selenium in Sediment at Station C (1996 - 2002)

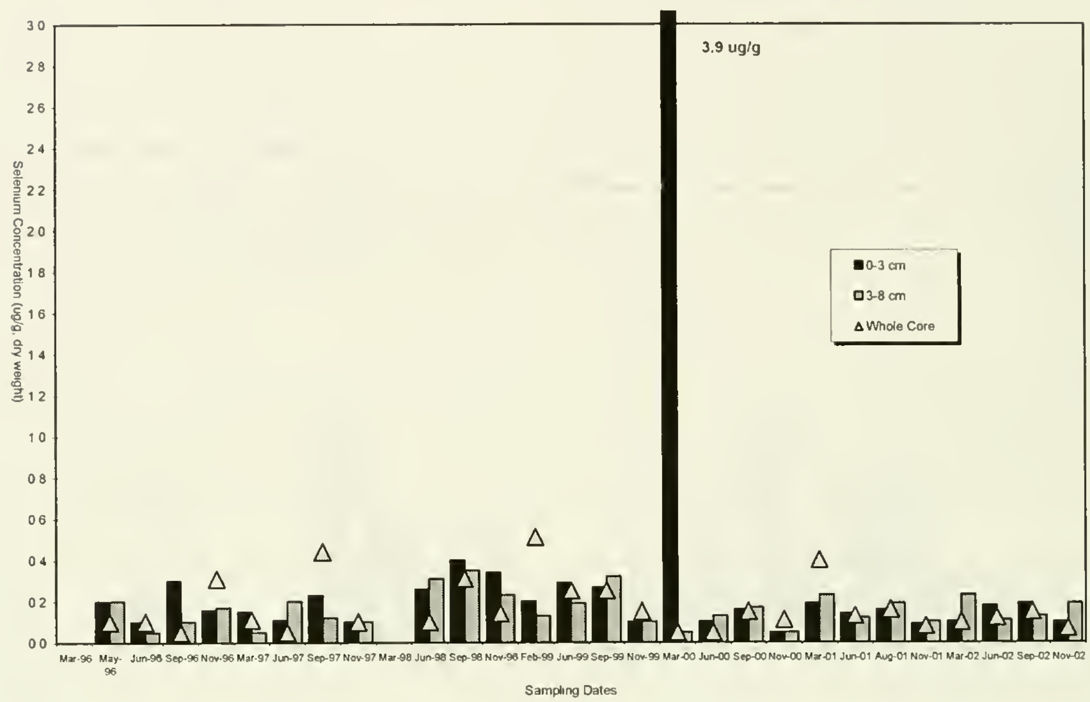


Figure 4. Selenium in Sediment at Station D (1996 - 2002)

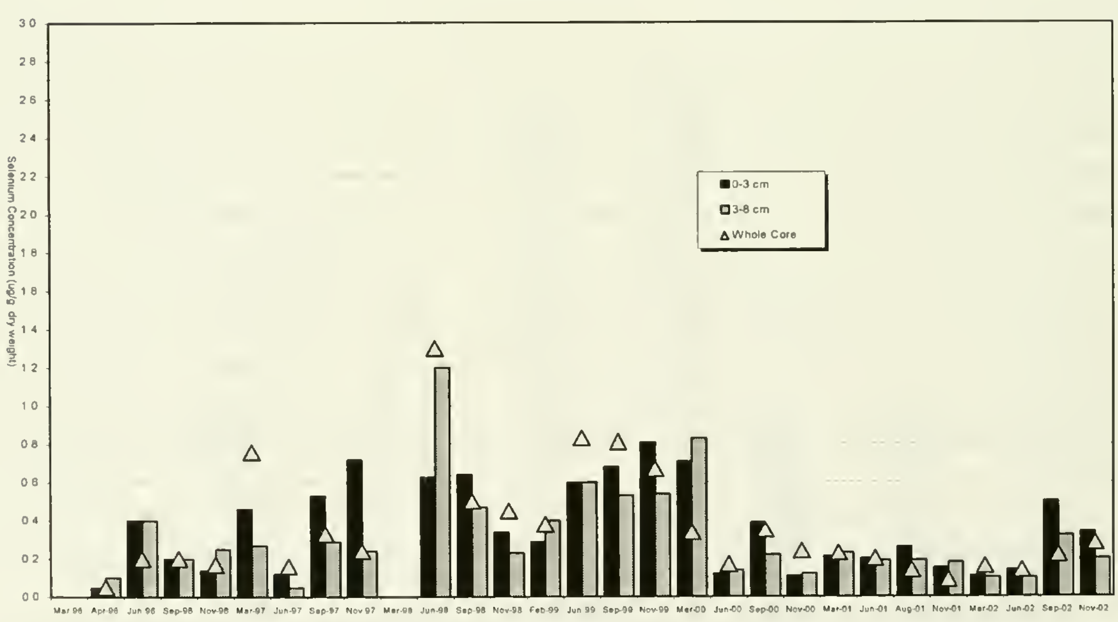


Figure 5. Selenium in Sediment at Station E (1996 - 2002)

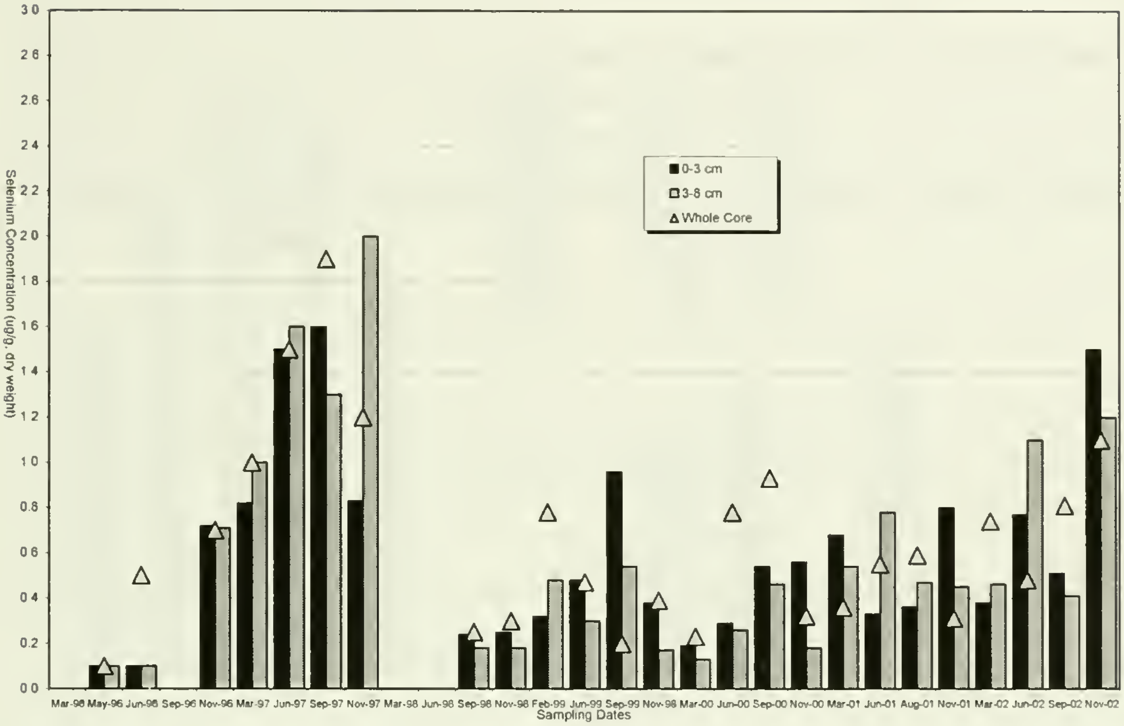


Figure 6. Selenium in Sediment at Station F (1996 - 2002)

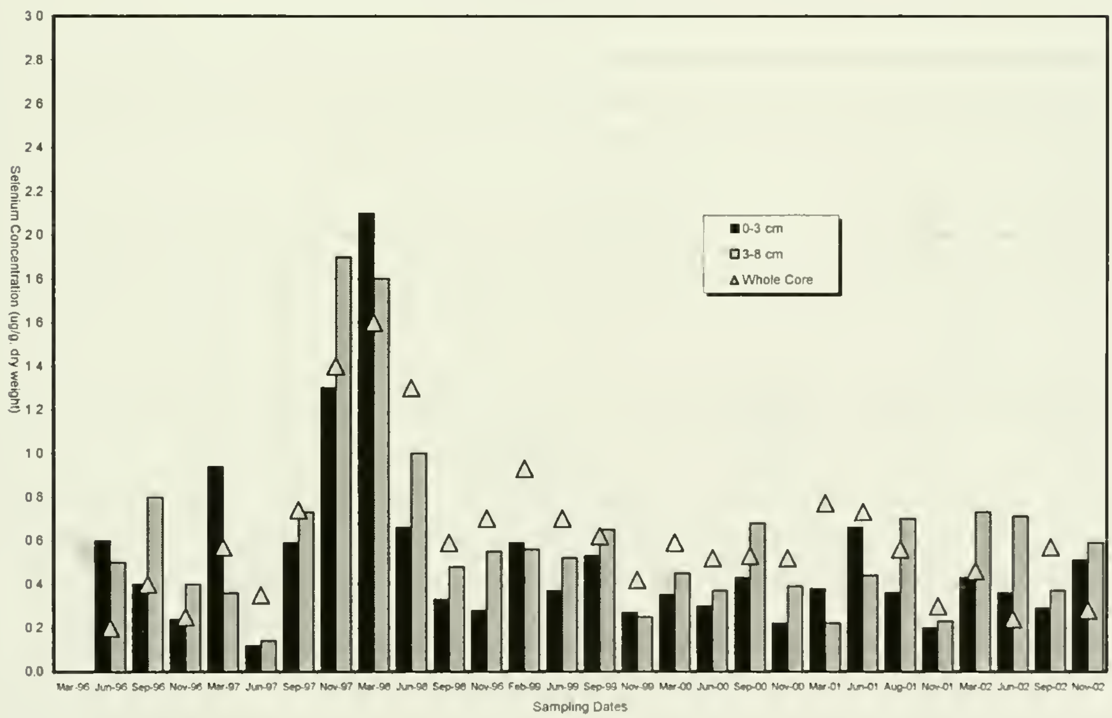


Figure 7. Selenium in Sediment at Stations I and I2 (1996 - 2002)

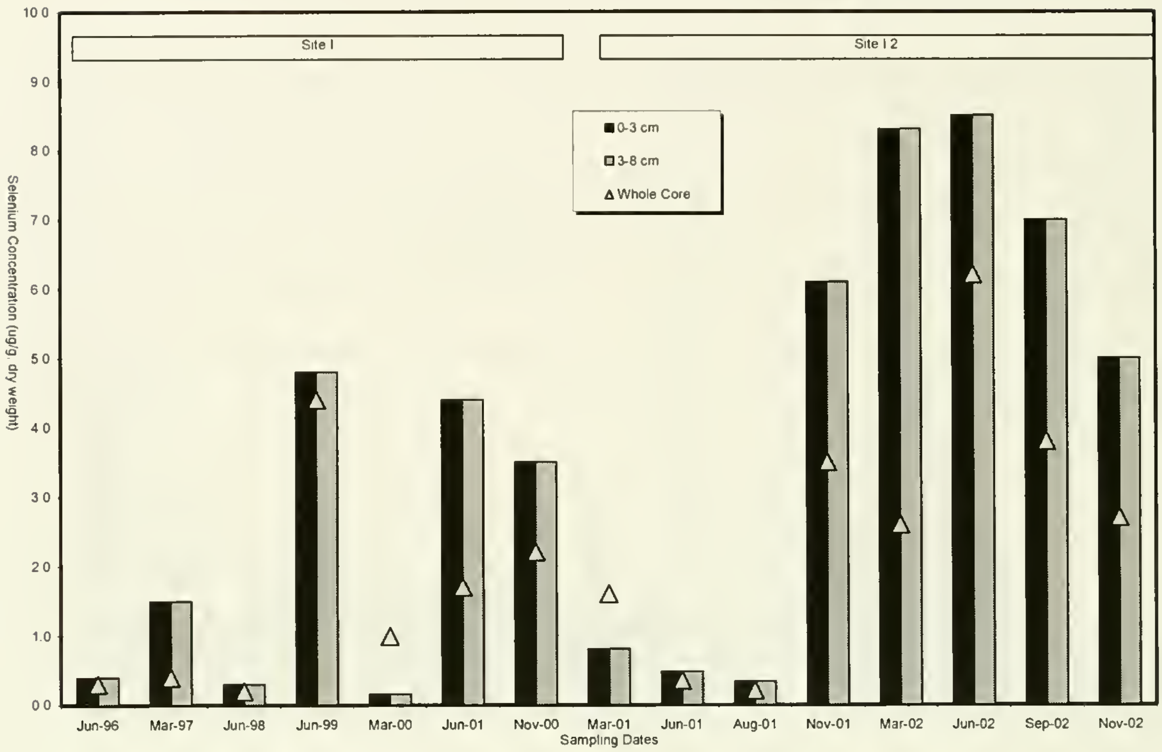
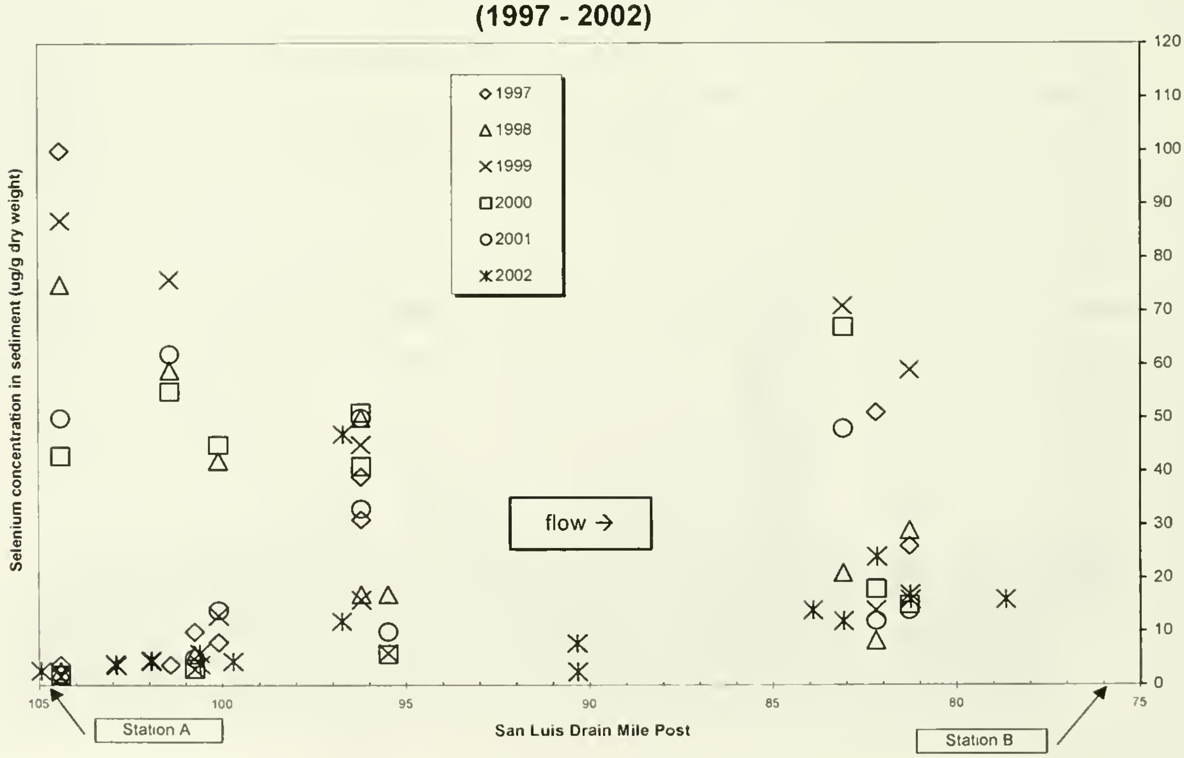


Figure 8. Selenium in Whole Core Samples of Sediment in the San Luis Drain (1997 - 2002)



10

Sediment Quantity in the San Luis Drain

October 1, 2001 – December 31, 2002

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Grassland Bypass Project

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Grassland Area Farmers

The purpose of this aspect of the Grassland Bypass Monitoring Program (Monitoring Program) is to determine the changes in quantity and movement of sediment in the San Luis Drain (SLD). This is accomplished by actual measurement of the bed sediment and using total suspended solids measurements at the inlet and outlet of the SLD.

Sediment Quantity Monitoring Procedure

Section 11.4 of the Compliance Monitoring Program Phase II (USBR et al., 2001) describes the procedure to measure the quantity of sediment in the SLD. The Monitoring Program calls for the measurement of sediment in four reaches of the SLD (Reaches 1, 10, 14, and 17). The locations of the sediment measurement points duplicated those of the March of 1987 survey performed by Summers Engineering. San Luis & Delta-Mendota Water Authority Personnel performed the sediment survey in November of 2002. The sediment bed was cross-sectioned at regular intervals in all 19 reaches of the SLD, with depth-to-sediment measurements taken at both banks and in the middle of the channel. These three measurements were used to calculate an average volume of sediment per foot of channel, which was then used to estimate the total volume of sediment in the SLD from Check 19 to the outlet at Mud Slough (North).

Table 1 summarizes the results. The results are also shown graphically in Figure 1. The results indicate that there is a net increase of 22,700 cubic yards from November 2001 to November 2002, compared to a net increase of 25,700 cubic yards from July 1999 to August 2000 and 21,400 cubic yards from August 2000 to November 2001. An estimated total of 97,900 cubic yards of sediment has accumulated in the SLD since 1997.

Survey measurements indicated that individual reaches of the SLD gained a maximum of 3,800 cubic yards (Pool 14), and lost a maximum of 160 cubic yards (Pool 16) as compared to the 2001 sediment survey. The average depth of sediment throughout the SLD was 2.6 feet, with a maximum depth of 6.7 feet measured in Pool 15 (see Figure 2).

In general, sediment accumulation is occurring in the first 5 reaches (Pools 18 to 14), as the suspended solids drop out of the water column upon entering the SLD. The water velocity within the SLD is kept below 1 foot per second to prevent the suspension of material from the sediment bed. The slower velocity also increases the rate at which suspended solids drop out of the water column.

Total Suspended Solids Measurements

The Monitoring Program calls for total suspended solids (TSS) measurements as part of the water quality monitoring. These measurements were to be taken just downstream of the inlet to the SLD (Site A) and just upstream of the outlet (Site B). Measurements were taken on a weekly basis at these sites. The monthly averages are shown for WY 1997 through December 2002 in Table 2. Overall, the 2002 data (including the last three months of 2001) show that TSS concentrations at Site A are higher than at Site B by a factor of 2.5, averaged over the entire 15 month period. One commitment of the GBP was to minimize flows so as to not cause sediment movement or suspension of sediments from the bottom of the SLD. The data suggest that the

suspended sediments are settling in the SLD and that there is no net movement or suspension of sediments.

References

U.S. Bureau of Reclamation et al. 2001. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, Phase II, March 2002. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

U.S. Bureau of Reclamation et al. 1996. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, September 1996. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

Table 1. 2002 San Luis Drain Sediment Survey
Survey Summary and Comparison

Pool	Checks	Distance	March 1987		June-Sept. 1997		July 1998		July 1999		August 2000		November 2001		November 2002	
			Volume	Vol / mile	Volume	Vol / mile	Volume	Vol / mile	Volume	Vol / mile	Volume	Vol / mile	Volume	Vol / mile	Volume	Vol / mile
		(miles)	(cu yd)	(cu yd/mi)	(cu yd)	(cu yd/mi)	(cu yd)	(cu yd/mi)	(cu yd)	(cu yd/mi)	(cu yd)	(cu yd/mi)	(cu yd)	(cu yd/mi)	(cu yd)	(cu yd/mi)
End	End to 1	2 64	3,176	1,203	1,697	643	2,795	1,059	3,602	1,364	4,451	1,686	5,611	2,125	6,338	2,401
1*	1 to 2	1 82	2,567	1,410	1,840	1,011	3,375	1,854	4,514	2,480	5,306	2,915	5,487	3,015	7,661	4,209
2	2 to 3	0 28	1,059	3,781	531	1,896	955	3,411	872	3,114	836	2,986	1,748	6,242	2,496	8,914
3	3 to 4	2 57	4,909	1,910	3,350	1,304	4,839	1,883	3,244	1,262	5,582	2,172	6,404	2,492	9,349	3,638
4	4 to 5	1 80	4,440	2,467	6,521	3,623	9,049	5,027	6,760	3,756	8,968	4,982	9,836	5,465	11,496	6,387
5	5 to 6	2 06	4,242	2,059	4,370	2,121	4,596	2,231	4,139	2,009	5,679	2,757	6,481	3,146	7,765	3,770
6	6 to 7	0.83	2,160	2,602	2,584	3,113	2,432	2,930	1,762	2,123	2,416	2,910	2,321	2,797	3,530	4,253
7	7 to 8	0 45	3,935	8,744	3,278	7,285	3,135	6,967	3,099	6,887	3,068	6,817	2,842	6,315	2,990	6,644
8	8 to 9	0 47	907	1,931	816	1,736	778	1,655	627	1,334	1,420	3,022	1,600	3,404	1,775	3,776
9	9 to 10	3 20	6,963	2,176	6,390	1,997	8,571	2,678	4,632	1,448	8,797	2,749	9,364	2,926	10,420	3,256
10*	10 to 11	1 46	2,647	1,813	2,708	1,855	2,781	1,905	3,101	2,124	3,669	2,513	3,835	2,626	4,975	3,408
11	11 to 12	2 50	4,835	1,934	4,947	1,979	7,620	3,048	6,499	2,600	10,194	4,078	10,900	4,360	13,692	5,477
12	12 to 13	0 46	784	1,705	909	1,977	1,504	3,270	629	1,367	2,274	4,942	1,966	4,273	2,324	5,052
13	13 to 14	0 91	2,038	2,240	1,771	1,946	2,657	2,920	2,709	2,977	3,835	4,215	4,378	4,811	5,884	6,466
14*	14 to 15	1 34	2,304	1,719	3,803	2,838	5,427	4,050	12,030	8,978	11,466	8,557	14,917	11,132	18,720	13,970
15	15 to 16	0 96	1,822	1,898	2,700	2,813	6,456	6,725	11,699	12,186	15,420	16,062	18,661	19,438	19,214	20,015
16	16 to 17	1 68	5,863	3,490	7,605	4,527	10,482	6,239	12,895	7,676	14,691	8,745	21,132	12,578	20,971	12,483
17*	17 to 18	0 68	1,885	2,772	3,006	4,420	2,435	3,581	3,205	4,713	3,477	5,113	4,900	7,206	5,318	7,821
18	18 to 19	0 97	1,558	1,607	1,768	1,822	2,519	2,597	2,603	2,684	2,819	2,906	3,427	3,533	3,571	3,681
Totals		27.08	58,094		60,594		82,406		88,621		114,368		135,809		158,489	
Averages				2,145		2,238		3,370		3,741		4,744		5,678		6 612

Data source Summers Engineenng Inc

Note * Required by Grassland Bypass Monitonng Program

Table 2. Total Suspended Solids (Monthly Average) October 1996 - December 2001

Date	Site A TSS mg/L	Site B TSS mg/L
Oct 96	92	38
Nov 96	59	8
Dec. 96	77	19
Jan. 97	135	23
Feb 97	57	31
Mar. 97	94	33
Apr. 97	111	38
May 97	101	56
Jun. 97	107	27
Jul. 97	136	21
Aug. 97	140	22
Sept 97	111	22
WY 1997 Average	102	28
Oct. 97	51	24
Nov. 97	86	19
Dec. 97	45	36
Jan. 98	61	24
Feb. 98	243	143
Mar. 98	290	114
Apr. 98	200	69
May 98	270	86
Jun. 98	123	42
Jul. 98	171	49
Aug. 98	94	44
Sept. 98	37	33
WY 1998 Average	139	57
Oct. 98	43	61
Nov 98	28	40
Dec. 98	19	30
Jan. 99	54	19
Feb. 99	149	50
Mar. 99	57	33
Apr. 99	43	38
May 99	97	60
Jun. 99	160	68
Jul. 99	145	65
Aug 99	166	61
Sept 99	69	71
WY 1999 Average	86	49

Date	Site A TSS mg/L	Site B TSS mg/L
Oct 99	73	57
Nov 99	62	43
Dec. 99	26	51
Jan 00	67	64
Feb. 00	250	71
Mar. 00	148	57
Apr. 00	134	69
May 00	165	45
Jun. 00	136	63
Jul. 00	99	53
Aug 00	120	58
Sept. 00	59	57
WY 2000 Average	111	57
Oct. 00	63	51
Nov 00	36	44
Dec. 00	46	46
Jan. 01	49	40
Feb. 01	108	33
Mar. 01	84	41
Apr. 01	67	41
May 01	188	46
Jun. 01	184	42
Jul. 01	142	41
Aug. 01	116	41
Sept. 01	65	pending
WY 2001 Average	96	42
Oct 01	164	39
Nov. 01	75	37
Dec. 01	32	42
Jan. 02	43	38
Feb. 02	108	36
Mar. 02	110	42
Apr. 02	58	30
May 02	193	51
Jun. 02	267	55
Jul. 02	138	51
Aug. 02	117	48
Sept. 02	96	36
WY 2002 Average	117	42
Oct. 02	73	49
Nov. 02	44	45
Dec. 02	60	39
Fifteen Month Average	105	42

Figure 1 - San Luis Drain Sediment Survey Comparison

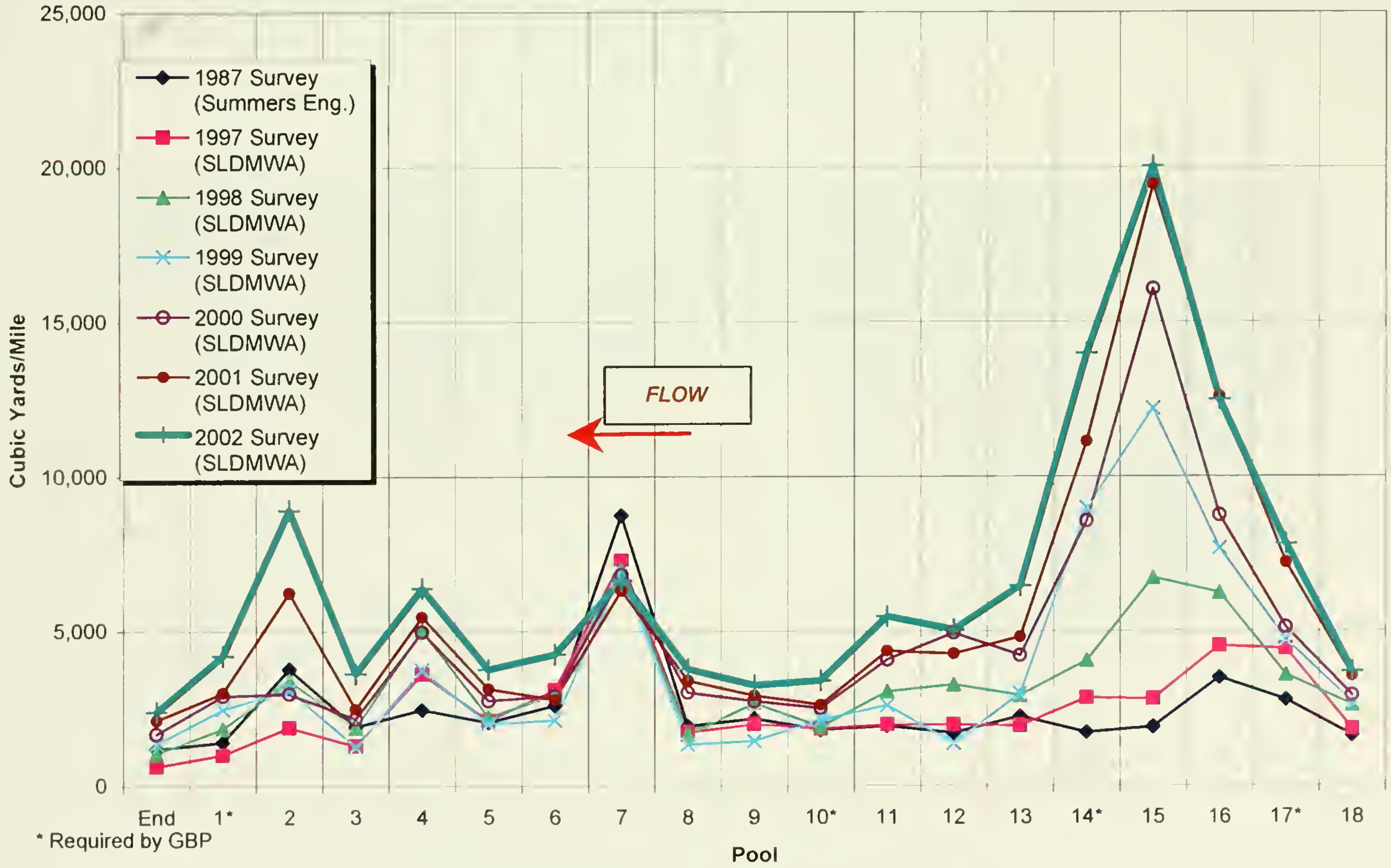
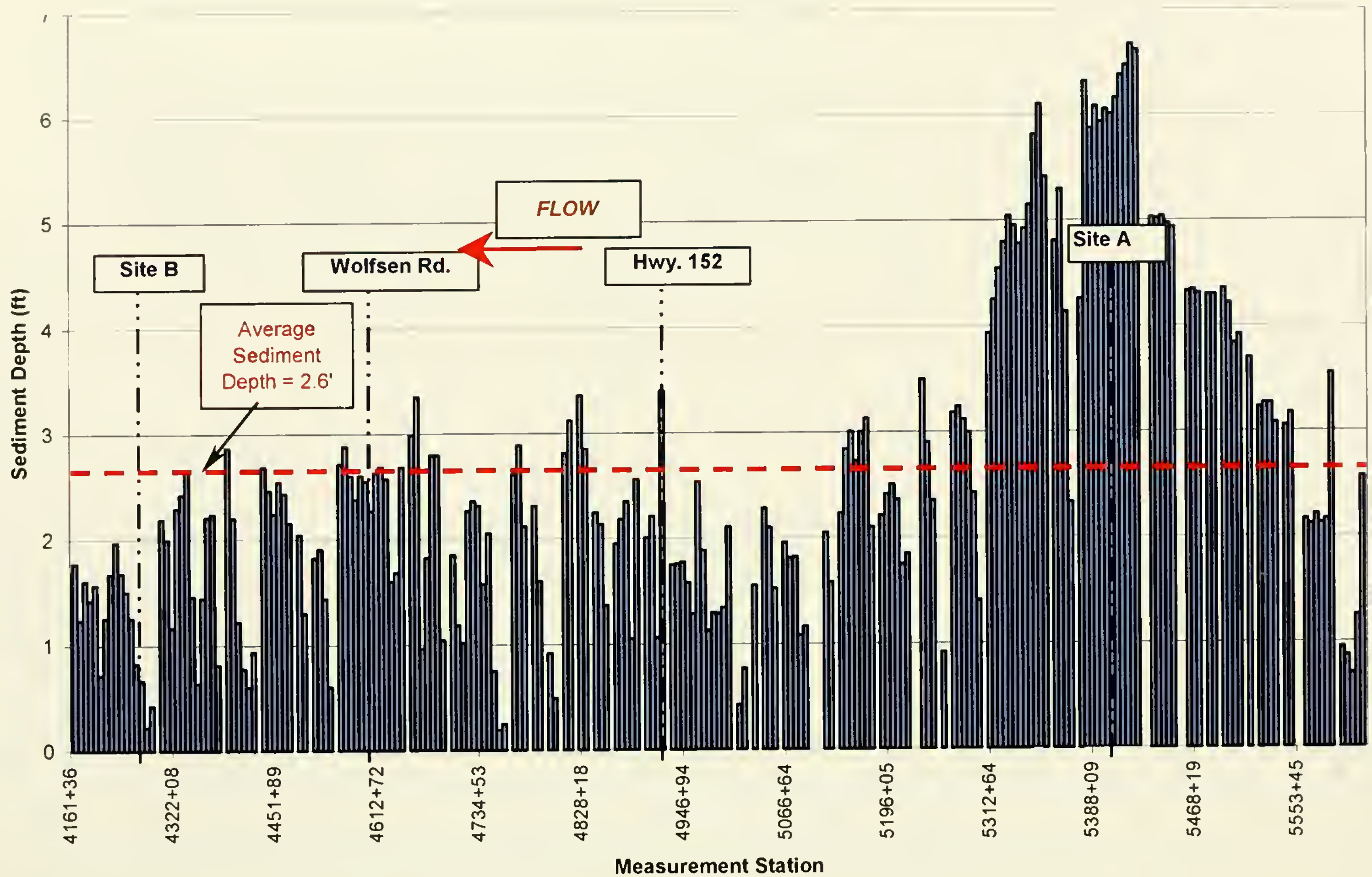


Figure 2: San Luis Drain November 2002 Sediment Depth



11

Quality Control

October 1, 2001 – December 31, 2002

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Grassland Bypass Project

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Data Quality Objectives

The Data Collection and Reporting Team (DCRT) uses the laboratory data from this project to support the determination of whether Selenium (Se) levels in the Grassland Bypass exceed regulatory compliance levels. Because individuals use the data generated by this program for regulatory compliance and baseline monitoring purposes, the data must be of the highest degree of reliability. Sample collection from different environmental media and analytical methods performed by the laboratories must adhere to the guidelines established in the quality assurance project plan (QAPP).

Quality Assurance Project Plan

The use and operation of the Grassland Bypass Project (GBP) was originally intended to extend over a five year time period (October 1, 1996 through September 30, 2001). However, on May 31, 2001, the U.S. Bureau of Reclamation (Reclamation) and the San Luis & Delta-Mendota Water Authority (Authority) completed an Environmental Impact Statement/Environmental Impact Report (EIS/EIR) on Phase II of the GBP. Phase II proposed extending the GBP to December 31, 2009. The EIS/EIR was needed to ensure that the continued use of the Project would be consistent with long-term drainage options and to ensure compliance with water quality objectives. On September 7, 2001, the California Regional Water Quality Control Board, Central Valley Region, adopted a Waste Discharge Requirement (WDR) for Phase II of the GBP that sets the terms and conditions for the use and operation of GBP through 2009. The WDR includes a schedule of monthly and annual selenium and salt loads that the GBP may discharge into Mud Slough (North) and the San Joaquin River, and specifies chronic toxicity testing. It also describes a program to monitor storm water releases from the Grassland Drainage Area (GDA) into the Grassland wetlands. On September 28, 2001, the Phase II Use Agreement (UA II), allowing the Authority to use the San Luis Drain from October 1, 2001 through December 31, 2009, was executed. The UA II established the terms and conditions for using the SLD and operating the GBP. The UA II required an extensive monitoring program to assess project accomplishments based on the WDR. As a result, the DCRT put in place a new Compliance Monitoring Program (CMP II) to monitor the environmental effects of the GBP. CMP II is based on the monitoring plan for the first Use Agreement that established the site locations, sampling frequency, parameters, and data reporting of project findings. The U.S. Bureau of Reclamation's Environmental Monitoring Branch was assigned the lead role to update the QAPP for Phase II of the Grassland Bypass Project.

On August 22, 2002, Reclamation and the DCRT completed and released the QAPP for Phase II of the use and operation of the Grassland Bypass Project. The QAPP provides the protocols for documenting the Quality Assurance/Quality Control (QA/QC) activities carried out by the agencies responsible for the separate components of CMP II. The QAPP describes the organization and membership of the project participants and defines the data quality objectives (DQOs) for CMP II. This plan describes the QA/QC activities associated with each agency=s monitoring program, provides the QA/QC protocol of each laboratory participating in the program, provides acceptance criteria for data validation procedures, and describes corrective actions to be taken when the data fails to meet such criteria. The QAPP addresses both

quantitative goals, including precision, accuracy, and completeness, and qualitative goals, including representativeness and comparability.

The updated QAPP follows the format described in the May 1994 Guidelines for Preparing Quality Assurance Project Plans, published by the State of California Department of Water Resources. The QAPP includes all the requirements identified in the August 1994 Draft Interim Final, US EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations, EPA QA/R-5.

Quality Assurance Oversight

QA/QC oversight for CMP II is the responsibility of a QA/QC manager (QAQCOM) working for Reclamation. The QAQCOM oversees the implementation of commitments, guidelines, practices, and protocols outlined in the QAPP in compliance with the goals and objectives of the project. The QAQCOM uses guidelines, protocols, and criteria established in the QAPP to monitor and validate data collected by Reclamation personnel and to assess the data collection and validation processes used by the other participating agencies. When the QAQCOM identifies a noncompliance issue, the appropriate QA Officer is notified, and the agency implements corrective actions to resolve the problem. The QAQCOM brings any unresolved issues between the QAQCOM and a participating agency's QA Officer to the attention of the DCRT for resolution. Reclamation personnel conduct audits of all participating analytical laboratories and review the data collection activities of the participating agencies for adherence to protocol. Agencies participating in CMP II also conduct field audits on other participating agencies by reviewing sampling methods in the field.

Quality Assurance Accomplishments

Laboratory Performance and System Audits

Table 1 is a list of laboratories that have been audited by Reclamation for the Project.

During 2002, Reclamation audited Twining Laboratories, Inc. and Frontier Geosciences, Inc. The audit process involves an initial demonstration of performance using external quality assurance samples (performance audit) followed by a review of the latest version of the laboratory's QA Manual, the laboratory's performance study results for the past three years, and the laboratory's most recent internal or external audit report with corrective actions. Once the laboratory has demonstrated acceptable performance and passed the initial document review process, Reclamation conducts an on-site system audit of the laboratory facility. During the on-site system audit, Reclamation reviews all of the detailed aspects of the quality system to ensure laboratory personnel understand and adhere to the protocols cited in the laboratory QA manual and that they follow the procedures outlined in the analytical methods. The auditors then send a report addressing all of the deficiencies identified during the system audit to the laboratory with a recommended time frame for the laboratory to respond to the findings and implement and document the corrective actions. The following tables are examples of how Reclamation summarized and documented performance sample results for Twining Laboratories, Inc. and Frontier Geosciences, Inc. in 2002 (Table 2 and 3).

The two laboratories audited by Reclamation in 2002 performed well on the performance and system audits. Where deficiencies were observed, the laboratories have incorporated the recommendations or are in the process of implementing them.

Sample Collection System Audits

Reclamation conducted a sample collection system audit on the San Luis & Delta Mendota Water Authority on April 24, 2002. The Authority collects water samples three times a month for Block Environmental Services (BES) at five different project sites for toxicity testing and selenium analysis. On June 12, 2002, the California Department of Fish and Game (CDFG) performed a sample collection system audit on the U.S. Fish and Wildlife Service (USFWS) at site I2. USFWS conducted a sample collection system audit on CDFG at site H on June 13, 2002. After completing the audits, USFWS and CDFG debriefed each other on their findings. For the GBP, USFWS and CDFG collect tissue samples for selenium, boron, and mercury analyses. The sample collection system audits focused on the quality of the environmental samples collected by the field samplers and the ability of field personnel to adequately support and document the sample collection process. The purpose of the sample collection system audits was to identify and prevent problems in the field that could compromise sample integrity. Even though the sample collection system audits found some deficiencies and deviations from stated protocols, overall the audits found Authority, CDFG, and USFWS field personnel to be very knowledgeable and skilled in collecting environmental samples for the Grassland Bypass Project. CDFG and USFWS personnel have remedied all deficiencies or deviations found during these field audits.

Data Review and Validation Activities

The routine data review and validation activities performed in 2002 to ensure data reliability as stated in the QAPP are listed in Table 4.

Data Validation Methods

The QAQCOM is responsible for ensuring the participating agencies properly validate their analytical results, identify problems with their analytical data, and contact their respective laboratories to initiate corrective actions. To accomplish these tasks, Reclamation routinely reviews and validates the data produced by the participating agencies.

Reclamation assesses the validity of the analytical results by comparing QC results to acceptance criteria identified in Table 7 of the QAPP. The guidelines address both internal and external QC sample results. The QAPP defines internal QC samples as those check samples incorporated by the laboratories performing the work and defines external QC samples as those check samples submitted to the laboratories by the contracting agency. Reclamation verifies that agencies are incorporating the correct numbers and types of external QC samples into batches of field samples during the data validation process and addresses any nonconformance issues with the agencies directly. Another assessment activity performed by Reclamation is to ensure participating agencies spike their external QC check samples or incorporate reference samples at concentrations near historical levels as a means of ensuring better sample accuracy.

Reclamation brings laboratory QC summary report problems to the attention of the each agency's QA Officer. The QA Officers then address these problems with the laboratories. For example, QA Officers may request laboratories take proper corrective actions on internal QC check sample results outside of established control limits. Reclamation checks data packages to ensure laboratories document details of their corrective actions in the case narrative section or as footnotes in the QC summary section. Reclamation also checks laboratory data packages to ensure the laboratories analyze project samples within required holding times.

Reviewing data packages to identify possible outliers is another part of the validation process. Once Reclamation staff identifies a data point as a possible outlier, they request the laboratory re-analyze the sample. Reclamation identified the selenium result of 1.2 ug/L for the BES water sample collected at Site B on February 20, 2002 as a potential outlier. From August 2001 through February 2002, selenium results from this site varied as follows: 32, 33, 32, 53, 56, 29, 53, 51, 30, 44, 47, 49, 55, 45, 47, 61, 56, 66, 61, 1.2, and 70 ug/L (Table 5). Upon re-analyzing the sample demonstrating the 1.2 ug/L selenium result, the laboratory confirmed the original result (Table 5). As a result, Reclamation concluded a sample switch had not occurred within the laboratory. Upon further investigation, Reclamation determined a water sample with a selenium concentration of 65 ug/L collected on February 20, 2002 demonstrated a historically high selenium value for the ambient site. The sample with the historically high 65 ug/L selenium result was also re-analyzed and the result confirmed. Reclamation concluded that sample bottles were incorrectly labeled in the field and the 1.2 ug/L selenium result was from the ambient site, and the 65 ug/L selenium result came from site B.

To assess both laboratory performance and field sampling homogenization techniques, Reclamation collected one duplicate sediment sample from Mud Slough and four duplicate sediment samples from the San Luis Drain and submitted them to the U.S. Geological Survey, Denver Laboratory for selenium analyses. These duplicate sample results (Table 6) provided information on both laboratory performance (precision) and field homogenization techniques. The values in Table 6 demonstrate acceptable analytical precision and sample homogenization techniques.

Reclamation also reviewed all field calibration sheets from each agency performing field sampling for documentation of routine instrument calibrations to ensure reliable field measurements.

QA Issues of Concern

To determine whether all deficiencies and deviations from stated protocols were corrected, Reclamation requires a corrective action report from BES responding to the findings in Reclamation's sample collection system audit report of the Authority on April 24, 2002.

On January 30th, 2004, the QAQCOM met with Staff of the Central Valley Regional Water Quality Control Board (CVRWQCB) to review the nutrient data collected and validated for sites C, G, and N from October 2001 to December 2002. During the review, a portion of the data was noted not to meet the GBP QAPP's quality assurance standards or the recovery criteria specified in the WDRs for Phase II of the GBP. Therefore, the QAQCOM concurred with the CVRWQCB's decision not to release that portion of the data.

On March 1, 2004, the QAQCOM called Randy Dahlgren of the University of California, Davis - Land Air and Water Resources Department Laboratory (UCD Laboratory) to request a review of the raw nutrient data his laboratory generated for sites B and D. However, the laboratory had destroyed all the raw nutrient data from October 2001 to December 2002. This review was necessary to determine if the UCD Laboratory collected and analyzed the nutrient samples following criteria established in the project's QAPP. Due to the UCD Laboratory's inability to provide the raw nutrient data, the QAQCOM determined that the nutrient data for sites B and D cannot be verified to determine if it meets the QAPP's quality assurance standards. As a result, none of the nutrient data for Sites B and D can be used for assessment purposes related to the Grassland Bypass Project.

The QAQCOM has instructed the laboratory currently analyzing the nutrient samples to retain raw data for a minimum of five years. As a result, the QAQCOM is confident nutrient data released in the future for the Grassland Bypass Project will meet the project's acceptance criteria as specified in the QAPP.

Uncertainty Associated with Environmental Measurements

As with all quantitative measurements, there is a degree of uncertainty associated with the values provided. This is especially true for environmental data where measurement error may be introduced in the sample collection phase as well as in the laboratory service phase. Program participants and the public need to understand that values presented in laboratory reports are not absolute, but rather represent values with associated precision and accuracy uncertainties as defined in Table 7 of the QAPP. In addition, as the concentration of the parameter approaches the limit of detection for the particular analytical method, the level of uncertainty of the result increases significantly as shown in Figure 4 of the QAPP. The data user needs to understand the degree of uncertainty or the confidence limits associated with the data.

Summary

During year 2002, the participating agencies in the Compliance Monitoring Program complied with all protocols outlined in the QAPP. Adherence to the QAPP ensured the reliability of the data collected and provided the necessary documentation to support the validity of the measurements. Where exceptions did occur, Reclamation was able to identify and address the issues, thereby ensuring the reliability of the project's data.

Reclamation took the lead role in 2002 updating the QAPP for Phase II of the use and operation of the GBP. During 2002, Reclamation conducted audits of two project laboratories and a sample collection system audit on the Authority for BES. CDFG performed a system audit of USFWS's sampling group and vice versa in 2002. Reclamation reviewed and validated the data collected throughout the year. In order to perform QA oversight duties, Reclamation requires full cooperation from the participating agencies. When using the data to make decisions, individuals need to understand the analytical uncertainty associated with the data. In performing QA oversight, Reclamation serves to remind agencies of the need to adhere to protocols established in the QAPP.

Table 1. Summary of Laboratory Audits Conducted by US Bureau of Reclamation

Laboratory	Location	Date(s)	Analysis Type
Trace Substance Laboratory	Rolla, Missouri	April 30 & May 1, 1996	Tissue Analysis
Severn Trent Services Laboratory	West Sacramento, California	October 10, 1996; July 10 & 11, 2001	Water Analysis
Frontier Geosciences Inc.	Seattle, Washington	February 2 & 3, 1998; September 4 & 5, 2002	Tissue Analysis
U.S. Geological Survey Geological Division Laboratory	Denver, Colorado	December 2 & 3, 1998 July 17 & 18, 2001	Sediment Analysis
Twining Laboratory	Fresno, California	June 22 & 23, 1999;	Water Analysis
South Dakota State University Olsen Laboratory	Brookings, South Dakota	September 23, 1999	Water Analysis
Water Pollution Control Laboratory	Rancho Cordova, California	January 13 & 14, 2000	Tissue Analysis
Weck Laboratories	City of Industry, California	August 10 & 11, 2000	Water Analysis
Block Environmental Laboratory	Pleasant Hill, California	September 28, 2000	Toxicity Analysis

Table 2. Twining Laboratories Performance Study

Sample ID	Parameter	Result mg/L	True Value mg/L	% Recovery	Acceptance Limit
QA475	Nitrate as N	2.6	2.8	93%	80 - 120
QA475	Ammonia as N	1.6	1.7	94%	80 - 120
QA475	Total Phosphorus	2	2.5	80%	80 - 120
QA476	Boron	0.27	0.28	96%	80 - 120
QA478	Total Suspended Solids	76	65.2	117%	80 - 120

Notes: Date completed 05/07/02
Matrix = Water

Table 3. Frontier Geosciences, Inc. Performance Study

Sample ID	Parameter	Result mg/kg	True Value mg/kg	% Recovery	Acceptance Limit
QA481	Boron	40	37.6	106%	80 - 120

Notes: Date Completed: 06/19/02
Matrix = Vegetation

Table 4. Data review and validation activities

Type of data & field logbooks	Review and Validation Group
Sediment data from Reclamation	Reclamation
Water data from CVRWQCB	Reclamation and CVRWQCB
Biota data from USFWS and CDFG	Reclamation and USFWS
Toxicity data from BES	Reclamation
Field logbooks from Reclamation's sampling group	Reclamation

Table 5. Block Environmental Site B Monitoring

	SELENIUM LEVELS (ug/L) AT SITE B				
	Result ug/L	Re-analyzed Result ug/L	Relative % Difference	Difference	Confirmation Acceptance Level
8/13/2001	32	-	-	-	-
8/15/2001	33	-	-	-	-
8/17/2001	32	-	-	-	-
9/10/2001	53	-	-	-	-
9/12/2001	56	-	-	-	-
9/14/2001	29	-	-	-	-
10/22/2001	53	-	-	-	-
10/24/2001	51	-	-	-	-
10/26/2001	30	-	-	-	-
11/26/2001	44	-	-	-	-
11/28/2001	47	-	-	-	-
11/30/2001	49	-	-	-	-
12/10/2001	55	-	-	-	-
12/12/2001	45	-	-	-	-
12/14/2001	47	-	-	-	-
1/28/2002	61	-	-	-	-
1/30/2002	56	-	-	-	-
2/1/2002	66	-	-	-	-
2/18/2002	61	-	-	-	-
2/20/2002	1.2	0.9	-	0.3	+ RL
2/22/2002	70	-	-	-	-

Table 6. Quality Assurance Results, Sediment Monitoring

Location	Selenium Level Regular Sample (ug/g)	Selenium Level Duplicate Sample (ug/g)	Relative Percent Difference (RPD) or Difference	Duplicate Acceptance Criteria
Site I_2 (whole core)	6.2	5.5	13%	≤ 35%
Site B (whole core)	16.0	18.0	11%	≤ 35%
Site 1-2C (whole core)	16.0	18.0	11%	≤ 35%
Check #13 (whole core)	4.5	4.6	2.2%	≤ 35%
Check #15C (whole core)	4.7	4.8	2.1%	≤ 35%

Notes: CONDUCTED JUNE 18, 19, 24, 25, 2002
DUPLICATES TO MEASURE LABORATORY PRECISION

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